RPT-192

Annual Performance Report for In Situ Bioremediation Operations, October 2004 to September 2005, Test Area North, Operable Unit 1-07B

May 2006

Idaho Cleanup Project

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Idaho Cleanup Project
Idaho Falls, Idaho 83415

Prepared for the
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Assistant Secretary for Environmental Management
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ABSTRACT

This report documents progress of the in situ bioremediation remedial component of the Test Area North, Operable Unit 1-07B remedial action during Fiscal Year 2005. Activities performed during this reporting period were conducted as part of the Initial Operations Phase of the remedy. The goal of the Initial Operations Phase is to eliminate flux of volatile organic compounds from the source area to downgradient locations, specifically TAN-28 and TAN-30A. This reporting period includes (1) completion of the alternate electron donor optimization in June 2005 to evaluate the effectiveness of whey powder in comparison to sodium lactate, and (2) routine injections and subsequent groundwater monitoring from July 2005 through September 2005. The alternate electron donor optimization provided evidence that whey powder is a more efficient and cost-effective electron donor than sodium lactate. As a result of the alternate electron donor optimization, a decision was made to switch the electron donor used at TAN from sodium lactate to whey powder. In addition, a new injection strategy to enhance electron donor distribution was developed in order to achieve the remedial goals of the Initial Operations Phase. This new injection strategy is recommended in this report and will work toward achieving the goals of effectively distributing electron donor to the entire source area, sustaining efficient conditions for anaerobic reductive dechlorination of trichloroethene to ethene, and cutting off flux of volatile organic compounds from the residual source.

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ACRONYMS

AED	alternate electron donor
ARD	anaerobic reductive dechlorination
ASTU	Air Stripper Treatment Unit
bgs	below ground surface
COC	contaminant of concern
COD	chemical oxygen demand
DCE	dichloroethene
E/E/M	ethene, ethane, methane
FDR	Field Demonstration Report
FER	Field Evaluation Report
FY	fiscal year
GC-FID	gas chromatography/flame ionization detector
GWTF	Groundwater Treatment Facility
IC	ion chromatography
INL	Idaho National Laboratory
IRC	INL Research Center
ISB	in situ bioremediation
MCL	maximum contaminant level
MS/MSD	matrix spike/matrix spike duplicate
NA	not available
OU	operable unit
PCE	tetrachloroethene
PDO	Predesign Operations
PDP	Predesign Phase
PE	performance evaluation

QA	quality assurance
RAWP	Remedial Action Work Plan
RPD	relative percent difference
SAP	Sampling and Analysis Plan
SPME	solid-phase microextraction
TAN	Test Area North
TBD	to be determined
TCE	trichloroethene
TPR	technical procedure
TSF	Technical Support Facility
VC	vinyl chloride
VFA	volatile fatty acid
VOC	volatile organic compound

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1. INTRODUCTION

The purpose of this report is to document the progress of in situ bioremediation (ISB) operations as a remedial action at the Test Area North (TAN) Operable Unit (OU) 1-07B of the Idaho National Laboratory (INL). This annual report provides a description of ISB activities for the reporting period October 2004 to September 2005. Section 1 presents an overview of the OU 1-07B remedy and the ISB remedial component. Section 2 provides a summary of the alternate electron donor (AED) optimization. Section 3 presents a summary of the ISB activities conducted from July 2005 through September 2005. Sections 4 through 6 discuss results, conclusions, and recommendations from activities performed and data generated throughout Fiscal Year (FY) 2005, which is the reporting period for this document.

Reporting for the AED optimization, conducted from March 2004 through June 2005, was initially included, in part, in the 2004 ISB annual report (Macbeth et al. 2005). In order to present the collective data set specifically describing the activities, results, conclusions, and recommendations for the entire AED optimization timeframe, a detailed report is included in Attachment A of this report. Attachment A is provided on a CD attached to this document. Also on CD, Attachment B contains all of the ISB data collected during this reporting period (October 2004 through September 2005).

1.1 Overview of the Operable Unit 1-07B Remedy and the In Situ Bioremediation Remedial Component

OU 1-07B is the final remedial action for the Technical Support Facility (TSF) -05 Injection Well and the surrounding groundwater contamination located within TAN. Historical records provide little definitive information on the types and volumes of organic wastes disposed of into the groundwater via the injection well. It is estimated that as little as 1,325 L (350 gal) or as much as 132,489 L (35,000 gal) of trichloroethene (TCE) may have been disposed using the injection well during its period of operation. Table 1-1 is a list of contaminants of concern (COCs) in the vicinity of TSF-05 that was established in the *Record of Decision, Declaration for the Technical Support Facility Injection Well (TSF-05) and Surrounding Groundwater Contamination (TSF-23) and Miscellaneous No Action Sites Final Remedial Action* (DOE-ID 1995).

Table 1-1. Contaminants of concern in the vicinity of the TSF-05 injection well (established in 1995 Record of Decision).

Contaminant	Maximum Concentrations[a]	Federal Drinking Water Standard
VOLATILE ORGANIC COMPOUNDS		
Trichloroethene (TCE)	12,000 – 32,000 ppb[b]	5 ppb[c]
Tetrachloroethene (PCE)	110 ppb	5 ppb[c]
cis-1,2-Dichloroethene (DCE)	3,200 – 7,500 ppb	70 ppb[c]

Table 1-1. (continued).

Contaminant	Maximum Concentrations[a]	Federal Drinking Water Standard
trans-1,2-DCE	1,300 – 3,900 ppb	100 ppb[c]
RADIONUCLIDES		
Tritium	14,900 – 15,300 pCi/L[d]	20,000 pCi/L
Strontium-90	530 – 1,880 pCi/L	8 pCi/L
Cesium-137	1,600 – 2,150 pCi/L	119 pCi/L[e]
Uranium-234	5.2 – 7.7 pCi/L[d]	27 pCi/L[f]

COC = contaminant of concern ppb = parts per billion pCi/L = picocuries per liter

a. The concentration range is taken from measured groundwater concentrations at the TSF-05 injection well (INEEL 1999).

b. Higher TCE concentrations were detected during Phase A surge-and-stress pumping of the TSF-05 injection well.

c. ppb is a weight-to-weight ratio that is equivalent to micrograms per liter (μg/L) in water.

d. Maximum concentrations of tritium and U-234 are below federal drinking water standards and baseline risk calculations indicate a cancer risk of 3×10^{-6}. While this risk is smaller than 1×10^{-4}, both tritium and U-234 are included as COCs as a comprehensive plume management strategy.

e. The MCL for Cs-137 is derived from a limit of 4 millirem per year (mrem/yr) cumulative dose-equivalent to the public, assuming a lifetime intake of 2 liters per day (L/day) of water.

f. The federal drinking water standard for U-234 is for the U-234, -235, and -238 series.

The OU 1-07B TCE-contaminated groundwater plume emanates from the TSF-05 injection well and extends approximately 2 mi downgradient. To remediate the separate areas of the plume, which have distinctly different levels of contamination, the plume was divided into the following three zones (shown in Figure 1-1):

- Hot spot
- Medial zone
- Distal zone.

A multi-component remedy was designed to address these three zones, as described in the *Record of Decision Amendment for the Technical Support Facility Injection Well (TSF-05) and Surrounding Groundwater Contamination (TSF-23) and Miscellaneous No Action Sites Final Remedial Action* (DOE-ID 2001). The components of the overall remedy include ISB for the hot spot, pump and treat for the medial zone, and monitored natural attenuation for the distal zone. Progress of remedies conducted in the medial and distal zone is documented in separate annual reports.

A number of operational phases were designed to assess the effectiveness of the ISB remedy over time. Table 1-2 presents an overview of the phases used for the implementation of ISB in the hot spot since the inception of ISB activities in 1998. Future activities (October 2005 and beyond) planned for ISB of the hot spot are described in Section 1.1.2.

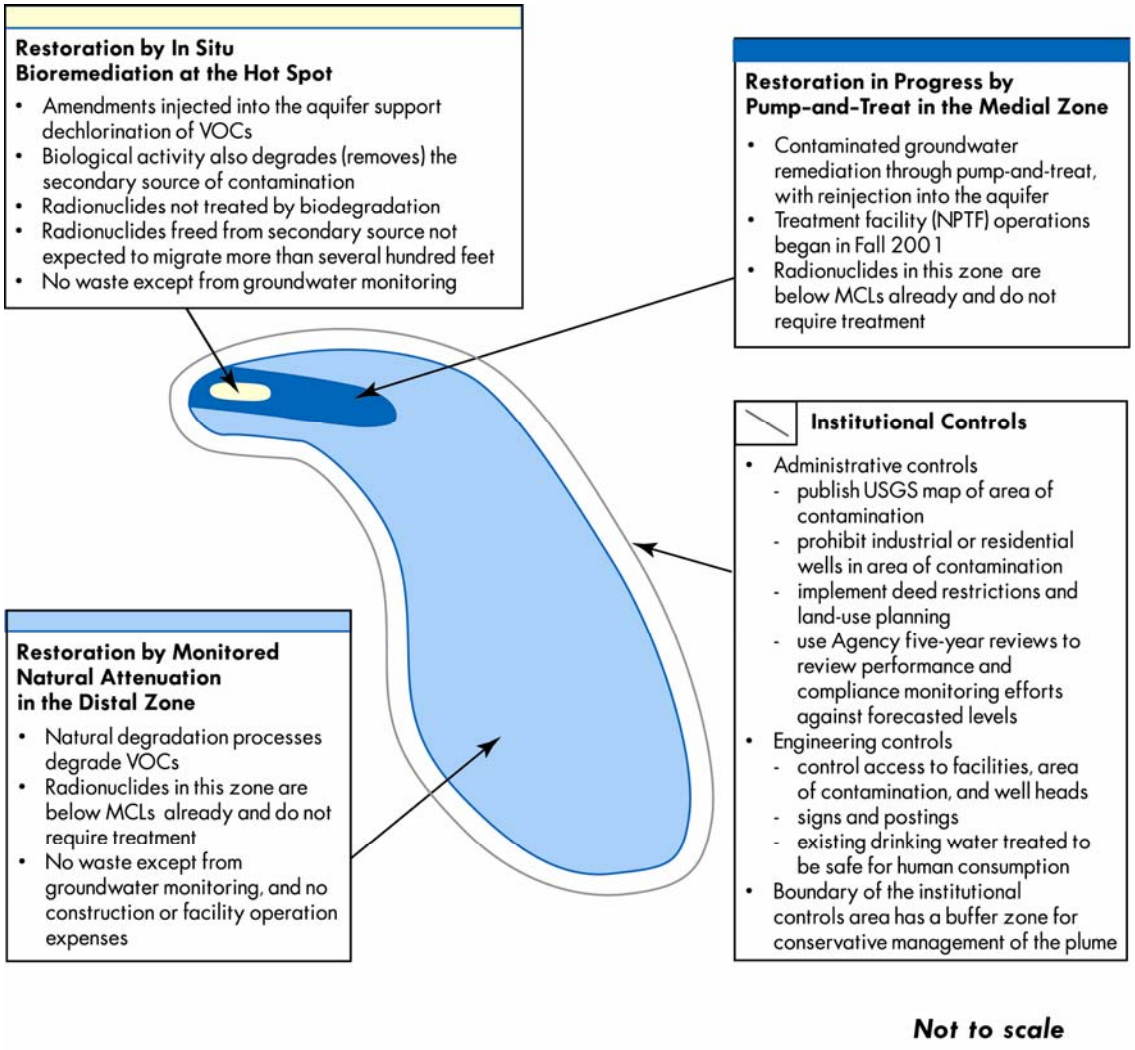

Figure 1-1. Conceptual illustration of the three zones of the trichloroethene plume.

Table 1-2. Overview of the operational phases for in situ bioremediation implementation in the hot spot.

Phase	Field Evaluation	Predesign Phase I	Predesign Phase II	Predesign Operations	Interim Operations	Initial Operations	Optimization and Long-Term Operations
Dates	November 1998 – September 1999	October 1999 – January 2000	February 2000 – April 2001	May 2001 – October 2002	November 2002 – October 2003	November 2003 – ongoing	TBD
Operations	Small, frequent (weekly/biweekly) lactate injections; groundwater monitoring.	No lactate injections; groundwater monitoring.	Relatively large volume, infrequent (bimonthly) lactate injections; groundwater monitoring; lab studies.	Relatively large volume, infrequent (bimonthly) lactate injections; groundwater monitoring; lab studies.		Alternating monthly lactate injections in two wells for 4 months; AED field optimization March 2004–June 2005; whey powder injections; groundwater monitoring.	Implement injection strategy to achieve maximum cost effectiveness; continue groundwater monitoring.
Overall Objective	Determine whether TCE dechlorination could be enhanced though the addition of an electron donor.	Monitor ARD reactions under propionate fermentation conditions in the absence of regular lactate injections.	Recreate the conditions for efficient ARD observed during PDP-I.	Continue to operate ISB system while performing construction and setup of ISB injection system.		Continue system operation while reducing downgradient flux of VOCs from the hot spot.	Continue system operation, while reducing and eventually eliminating downgradient and crossgradient flux of VOCs from the hot spot.
Results	Complete ARD to ethene observed; ISB selected as hot spot remedy.	ARD efficiency increased under propionate utilization conditions in the absence of lactate fermentation.	Conditions conducive to ARD maintained within the biologically active area. Distribution of lactate throughout residual source area not achieved.	Conditions conducive to ARD maintained within the biologically active area. Distribution of lactate throughout the residual source area not achieved as indicated by continued flux of VOCs to downgradient locations.		TBD	TBD

Table 1-2. (continued).

Phase	Field Evaluation	Predesign Phase I	Predesign Phase II	Predesign Operations	Interim Operations	Initial Operations	Optimization and Long-Term Operations
Controlling Document	Field Evaluation Work Plan	Field Evaluation Work Plan	Field Evaluation Work Plan	PDO Work Plan	RAWP	RAWP	RAWP
Reports	FDR (DOE-ID 2000)/FER (INEEL 2000)	2001 Annual Report (INEEL 2002a)		2002 Annual Report (INEEL 2003a)	2003 Annual Report (Armstrong et al. 2004)	2004 Annual Report (Macbeth et al. 2005) and 2005 Annual Report	Annual Performance/ Compliance Reports

AED = alternate electron donor

ARD = anaerobic reductive dechlorination

FDR/FER = Field Demonstration Report/Field Evaluation Report

ISB = in situ bioremediation

PDO = Predesign Operations

PDP = Predesign Phase

RAWP = Remedial Action Work Plan

TBD = to be determined

TCE = trichloroethene

VOC = volatile organic compound

1.1.1 Activities Conducted During the Current Reporting Period

The *In Situ Bioremediation Remedial Action Work Plan for Test Area North Final Groundwater Remediation, Operable Unit 1-07B* (DOE-ID 2004a) and supporting documents, specifically the *In Situ Bioremediation Remedial Action Groundwater Monitoring Plan for Test Area North, Operable Unit 1-07B* (INEEL 2003b) and the *ISB Operations and Maintenance Plan for Test Area North, Operable Unit 1-07B* (DOE-ID 2004b), are the governing documents for the current ISB activities. All activities performed during this reporting period (October 2004 through September 2005) were conducted as part of the Initial Operations Phase. To determine if whey powder is a more cost-effective alternative to sodium lactate, the AED optimization was conducted. Results and recommendations of the entire AED optimization (March 2004 through June 2005) are summarized in Section 2, and a detailed report is provided in Attachment A.

1.1.2 Future Activities

The Initial Operations Phase will be complete when it is determined that downgradient flux of volatile organic compounds (VOCs) from the hot spot has been reduced such that VOC concentrations remain less than required maximum contaminant levels (MCLs) at TAN-28 and TAN-30A for a period of 1 year. Following completion of the Initial Operations Phase, two additional phases will follow, including:

- Optimization Operations Phase—This phase will focus on reducing the flux of VOCs from the hot spot in the crossgradient direction, as measured at TAN-1860 and TAN-1861, while maintaining VOC flux reduction in the downgradient direction. During this phase, data will continue to be gathered and analyzed relating to achievement of long-term performance objectives. Alternative operational strategies may be performed during this phase to enhance or optimize remedy performance.

- Long-Term Operations Phase—This phase will focus on achievement of hot spot source degradation, while maintaining the reduction of VOC flux from the hot spot in the crossgradient and downgradient directions.

The ISB Remedial Action Work Plan (DOE-ID 2004a) presents a complete description and the criteria for completion of each phase, as well as performance and compliance monitoring requirements. Progress of ISB activities compared to these requirements will be the focus of future reports.

1.2 Reporting Period Requirements

The current reporting period is part of the Initial Operations Phase. As specified in the ISB Remedial Action Work Plan (DOE-ID 2004a), the requirements during the Initial Operations Phase include:

- Focusing on reducing the flux of VOCs from the hot spot in the downgradient direction

- Routinely monitoring performance of the ISB system with respect to indicator parameters (including VOCs, tritium, ethene/ethane/methane, redox parameters, electron donor, bioactivity, and nutrients) to determine whether operational changes are required.

Each of the above requirements was performed during this reporting period and is discussed in subsequent sections of this document.

2. SUMMARY OF THE ALTERNATE ELECTRON DONOR OPTIMIZATION, MARCH 2004 THROUGH JUNE 2005

The objective of the AED optimization was to evaluate whether the use of whey powder as the electron donor for long-term ISB operations will improve system performance and decrease cost. The AED optimization was conducted from March 2004 through June 2005. Details of the entire AED optimization are included in Attachment A, while a summary of the field optimization is presented below. The approach and requirements for activities performed during the AED optimization are detailed in the *Alternate Electron Donor Optimization Plan for ISB Operations at Test Area North Operable Unit 1-07B* (Harris and Hall 2004).

2.1 Activities Performed

Activities performed during the AED optimization included two baseline sodium lactate injections, three whey powder injections, and groundwater monitoring. On March 15 and May 10, 2004, approximately 12,000 gal of 6% nominal concentration sodium lactate solution was injected into TSF-05 (Section A-3.1). On August 16, 2004; October 11, 2004; and January 10, 2005; approximately 12,000 gal of 10% w/w whey powder solution was injected into TSF-05 (Section A-3.2). Groundwater monitoring was conducted for all, or a selected subset of, ISB parameters following each injection (Section A-3.3). In addition, high-frequency sampling was conducted for five sampling locations (TSF-05A, TSF-05B, TAN-25, TAN-31, and TAN-1859) with samples collected the day after (Day 2) injection (Day 1), Day 8-10, Day 15, Day 22-23, Day 36-38, Day 64-65, and/or Day 71-73. The Day 8-10 and Day 36-38 sampling events were part of regular ISB sample collection, which was conducted for all ISB monitoring wells (Figure 2-1); one exception was that the collection of samples from TAN-9 began in April 2005.

2.2 Analysis of Groundwater Monitoring Data

This section summarizes the analysis of groundwater monitoring data collected during the AED optimization. Sampling for ISB parameters was conducted to evaluate electron donor distribution and utilization, geochemistry including redox conditions and biological activity indicators, and anaerobic reductive dechlorination including enhanced dissolution of contaminants from the residual source to the aqueous phase and the subsequent degradation performance to ethene. A summary of data collected for the AED optimization include the following:

- **Electron Donor—**Injection and distribution of electron donor creates a biologically active zone described by the volume of aquifer within which biological activity is stimulated by electron donor addition. At TAN, creation of a biologically active zone within the residual source area has resulted in degradation of TCE to below MCLs in locations where electron donor is distributed. Under ideal operating conditions, electron donor is distributed throughout the entire residual source area stimulating degradation of aqueous-phase contaminants to innocuous end products resulting in cessation of transport of VOCs to downgradient and crossgradient locations. At TAN, however, injections into TSF-05 and TAN-1859 (INEEL 2002a; INEEL 2003a; Armstrong et al. 2004; Macbeth et al. 2005) have not encompassed the entire residual source area, as indicated by continued flux of VOCs to TAN-28 (downgradient) and TAN-1860 and TAN-1861 (crossgradient). Therefore, evaluating the distribution and utilization of whey powder relative to sodium lactate was important in evaluating the effectiveness of using different electron donors on reaching remediation goals.

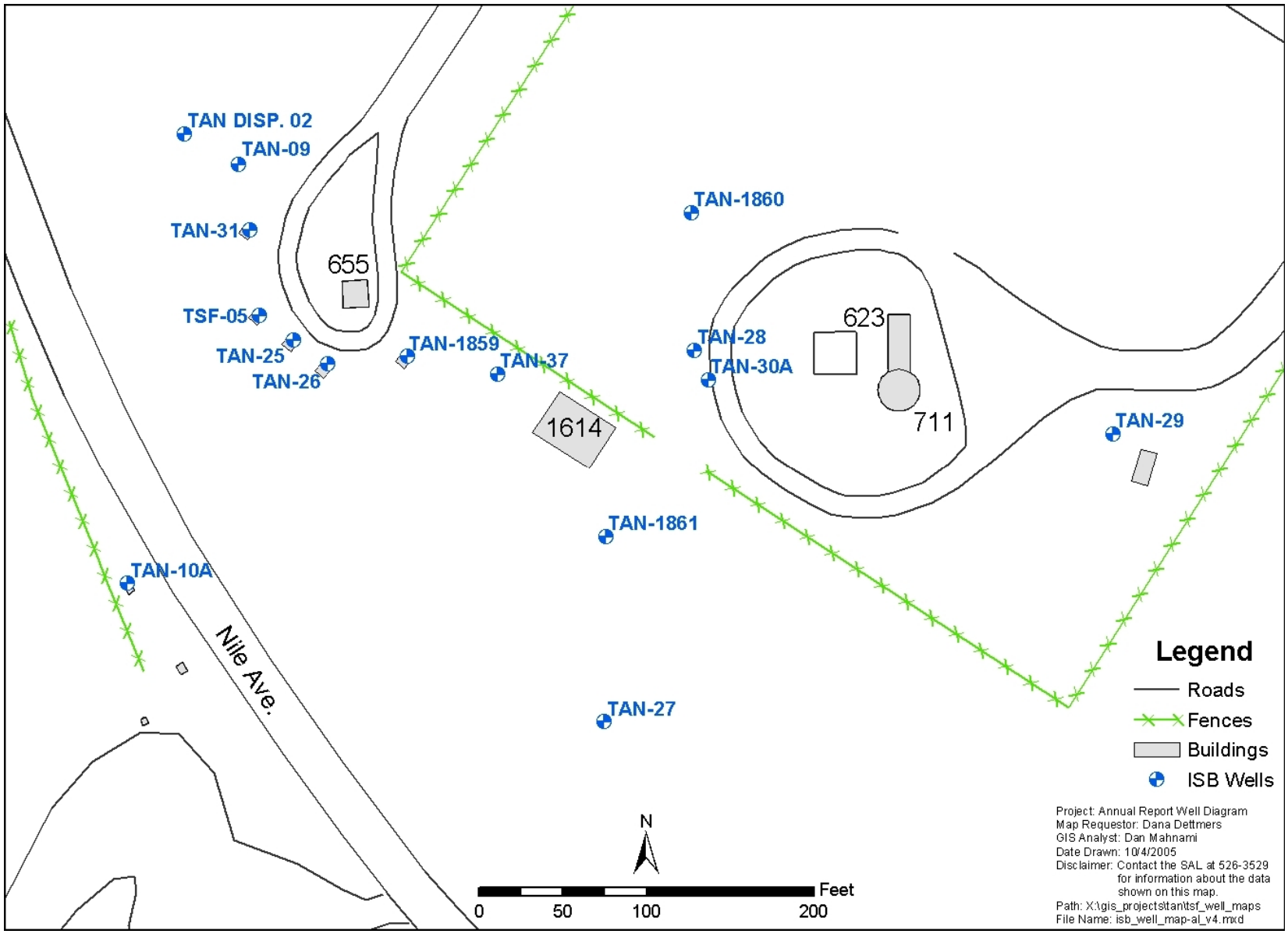

Figure 2-1. The in situ bioremediation monitoring well network.

- **Distribution.** Both donors were distributed approximately the same distance radially, as measured by the increased chemical oxygen demand (COD) observed in TAN-25, TAN-31, and TAN-1859 (Figure 2-2). The concentration of COD that reached these locations, however, was much higher (approximately factor of two greater) following whey powder injections, relative to that observed following sodium lactate injections (Figures 2-2, 2-3, and 2-4).

- **Utilization.** The utilization rate coefficients calculated for the primary substrate lactose for whey powder were at least twice as high following whey powder injections compared to the utilization rate coefficients calculated for primary substrate lactate following sodium lactate injections at Wells TSF-05A, TAN-25, and TAN-31. Although the utilization of the primary substrate was much higher for whey powder (lactose) than for sodium lactate (lactate), the overall utilization of electron donor following whey powder injections (as measured using the depletion of COD over the course of an injection cycle) was comparable at most wells to sodium lactate injections. This is due to the lower utilization of the fermentation daughter products, which consist of primarily butyrate, propionate, and acetate, generated from the degradation of lactose. Therefore, because the amendment strategy at TAN included injecting higher concentrations of whey powder into the biologically active zone compared to sodium lactate, the overall longevity of whey powder was greater than that of sodium lactate. Accordingly, the fermentation daughter products acetate, butyrate, and propionate persisted in the biologically active zone for longer following whey powder injections compared to sodium lactate injections.

- **Geochemical Parameters—**Geochemical parameters were monitored during the AED optimization as an indication of the achievement and/or maintenance of conditions suitable for contaminant degradation. Observing trends in redox parameters and biological activity indicators can provide a quick indication of the relative health of the system.

  - **Redox Conditions.** Throughout the AED optimization, redox conditions have remained methanogenic, as indicated by maintenance of negligible sulfate concentrations, elevated ferrous iron concentrations, and high concentrations of methane in wells where electron donor was distributed. Few differences in redox conditions were observed following the transition to whey injections with the exception of increases in sulfate concentration and decreases in methane concentrations in groundwater immediately following whey powder injections. It was determined that increases in sulfate resulted from the whey powder solution itself, but that the amended sulfate was depleted in less than one week following the injection. The increases in sulfate did not affect overall dechlorination performance (Figure 2-5).

  - **Biological Activity Indicators.** A reduction in pH was observed following whey powder injections and was attributed to the high fermentation rate of the lactose component of whey powder resulting in rapid generation of volatile fatty acids (VFAs). These pH drops were temporary and rebounded to pre-injection levels within 2 to 3 weeks following the injection. Alkalinity remained high (1,000 to 6,200 mg/L) throughout the AED optimization.

- **Anaerobic Reductive Dechlorination—**ARD was assessed during the AED optimization by measuring changes in the aqueous concentrations of parent compound (TCE), and reductive daughter products cis-DCE, vinyl chloride (VC), and ethene. ARD efficiency was measured by tracking the molar concentration conversion of parent compound to ethene. In addition, enhanced dissolution of TCE from the residual source material into the aqueous phase was assessed by measuring changes in concentrations of parent compounds directly after sodium lactate and whey powder injections.

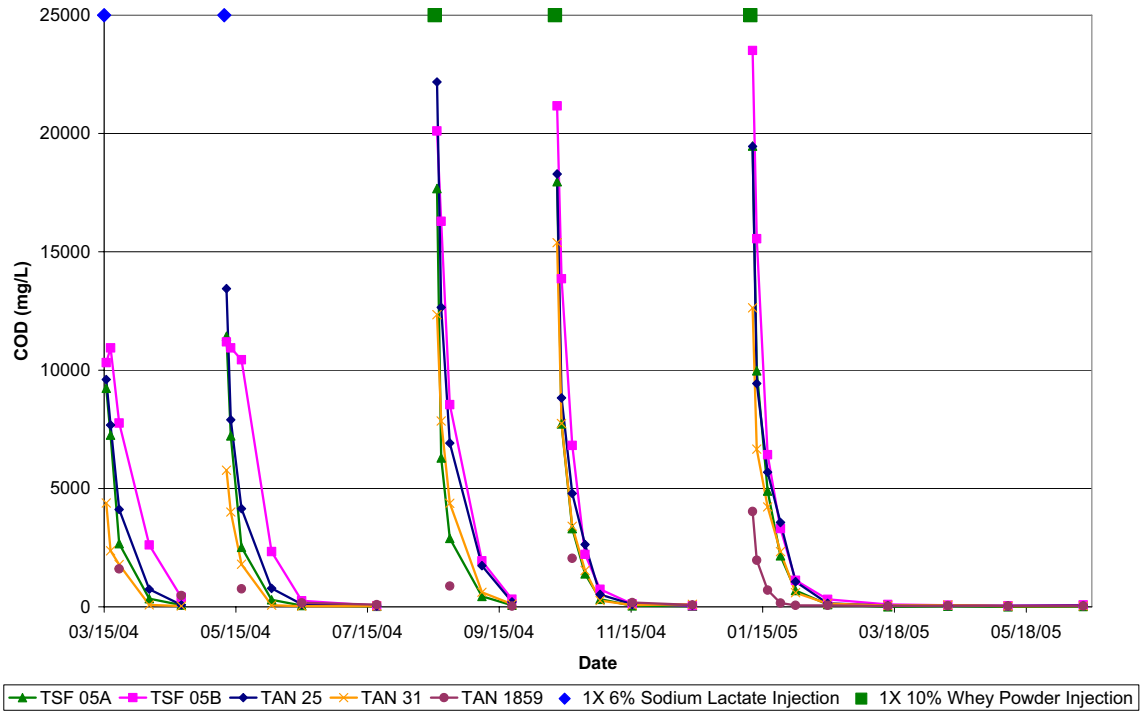

Figure 2-2. Chemical oxygen demand (COD) concentrations during the alternate electron donor optimization.

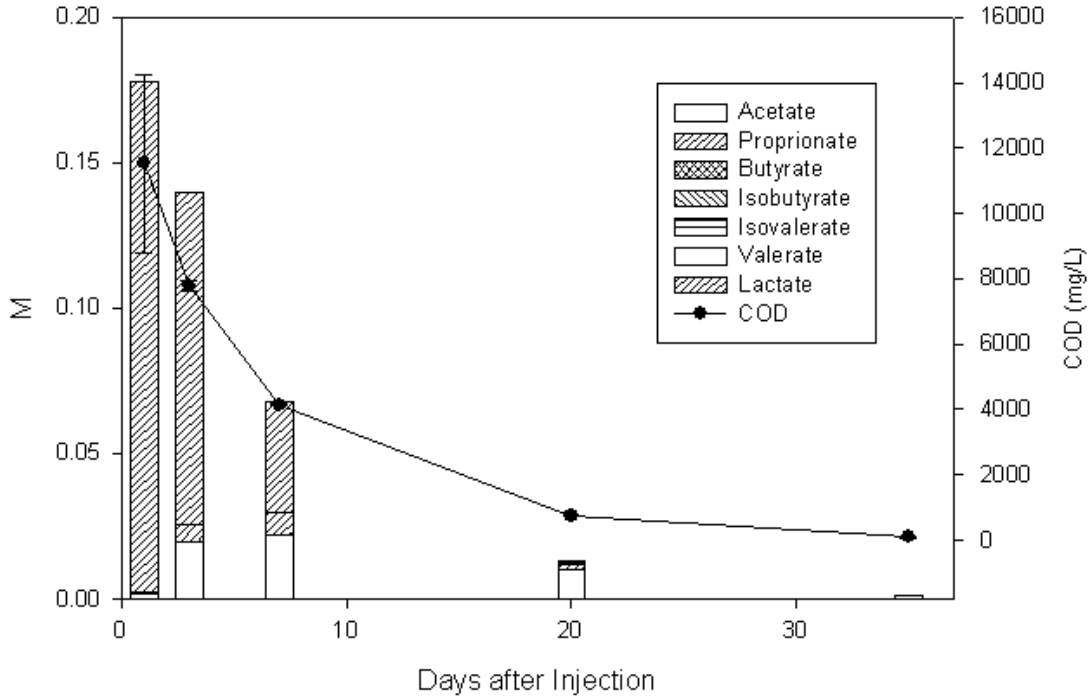

Figure 2-3. Average molar (M) electron donor concentrations and average COD at TAN-25 following the AED optimization sodium lactate injections.

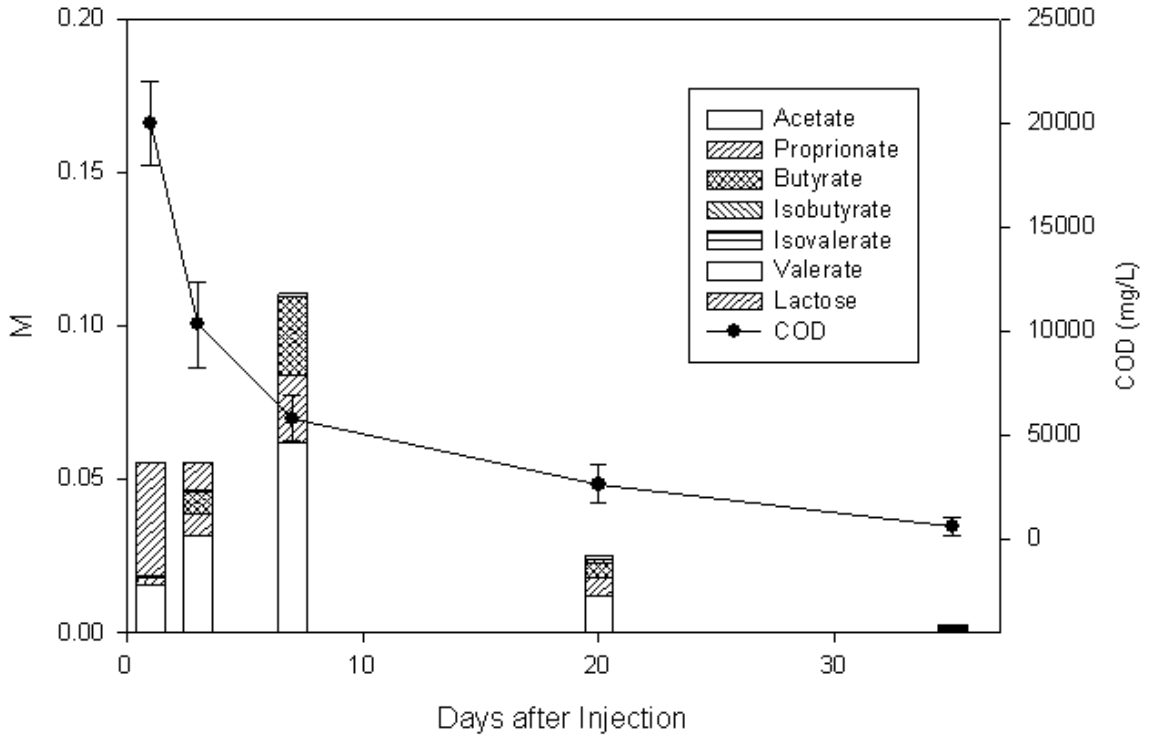

Figure 2-4. Average molar (M) electron donor concentrations and average COD at TAN-25 following the AED optimization whey powder injections.

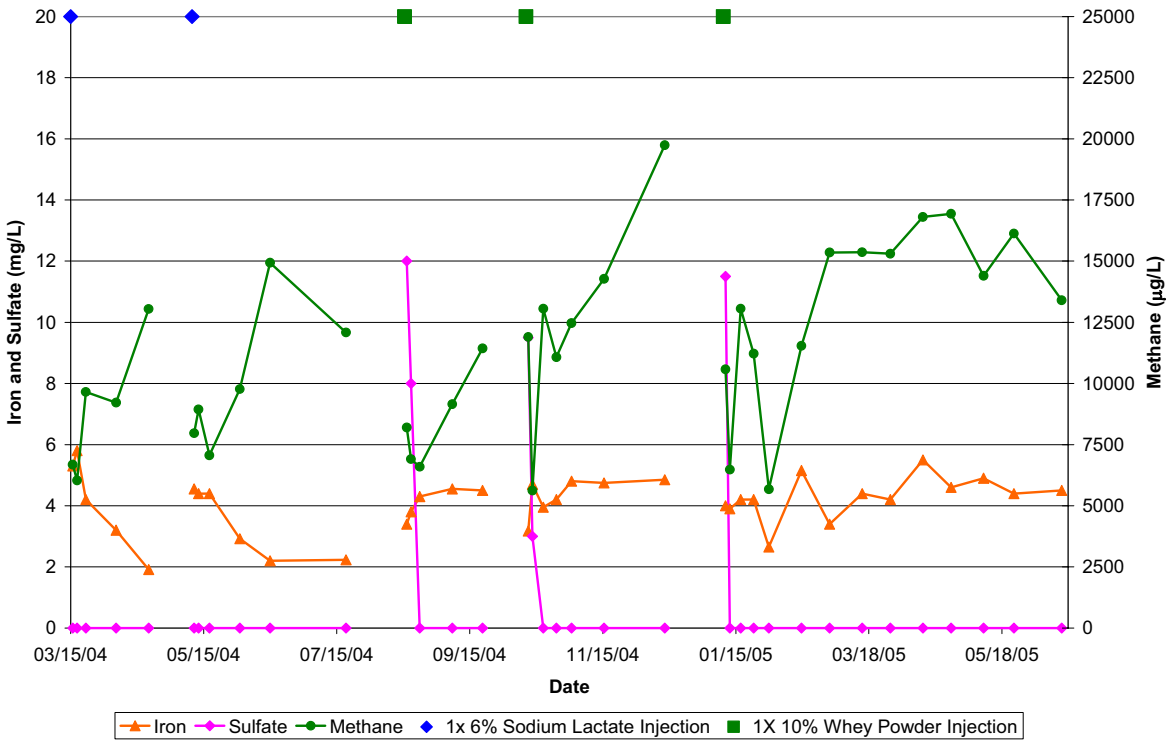

Figure 2-5. Redox conditions at TAN-25 during the alternate electron donor optimization.

- **Anaerobic Reductive Dechlorination Efficiency.** The efficiency of ARD reactions is assessed by examining changes in relative concentrations of TCE, cis-DCE, VC, and ethene. Throughout the AED optimization, ARD efficiency remained high, as evidenced by rapid degradation of TCE and production of the molar equivalent concentrations of ethene following both sodium lactate and whey powder amendment injections.

- **Enhanced Dissolution.** Whey powder injections into TSF-05 appeared to increase the dissolution of TCE from the residual source material when compared to the baseline sodium lactate injections. The increased dissolution effects are evidenced by substantial increases in TCE and cis-DCE concentrations on Days 2 and 4 in Wells TSF-05A, TSF-05B, TAN-25, and to a lesser extent in TAN-31, following whey powder injections, as compared to sodium lactate injections. For example, following sodium lactate injections, TCE concentrations were detected up to 13 µg/L and cis-DCE up to 82 µg/L at TAN-25; however, following whey powder injections, TCE concentrations were detected up to 395 µg/L and cis-DCE up to 327 µg/L at TAN-25 (Figure 2-6).

- **Radiological Monitoring—**Previous ISB Annual Reports (INEEL 2002a; INEEL 2003a; Armstrong et al. 2004; Macbeth et al. 2005) have indicated that radionuclides were being mobilized in the vicinity of TSF-05 in response to electron donor injections. Samples are collected annually and analyzed for Sr-90 in monitoring wells TSF-05A, TSF-05B, TAN-25, TAN-37A, TAN-37B, TAN-28, TAN-30A, and TAN-29 as part of Monitored Natural Attenuation activities (DOE-ID 2003). Monthly Sr-90 monitoring at TAN-25 was added as a parameter to be sampled only during the AED optimization for comparison of Sr-90 concentrations following sodium lactate and whey powder injections. During the AED optimization, spikes in Sr-90 concentrations were detected at TAN-25 following both sodium lactate and whey powder injections; however, increases were more pronounced following the whey powder injections. These increases are attributed to the initial drop in pH due to lactose fermentation; however, Sr-90 concentration spikes were transient and decreased to background concentrations as pH returned to near neutral levels (Figure 2-7). Historic Sr-90 concentrations in comparison to concentrations measured during the AED optimization are shown in Attachment A. Throughout the AED optimization, tritium concentration trends were not correlated to injection operations and remained relatively stable. Additional details are included in Attachment A.

- **Microbial Analysis—**Electron donor injections result in the sudden availability of high concentrations of readily degradable compounds that stimulate rapid microbial growth and activity. Therefore, studying microbial population dynamics over the course of an injection cycle provided information about the populations responsible for lactate and lactose utilization. Groundwater samples were collected from TAN-25 for microbial analysis during the AED optimization. Overall, diversity of *Bacteria* was lower following the whey powder injections than following the sodium lactate injections. In particular, the sample events conducted within one week following the whey powder injections illustrated substantially lower diversity. Likely, this is due to the stimulation of lactose-fermenting populations, which grew to numbers high enough to dominate the results of the analytical technique, which only detects populations that comprise greater than approximately 1% of the total community. A drop in diversity following sodium lactate injections also was observed, although to a much lesser extent relative to the whey powder, which was attributed to stimulation of lactate-fermenting populations. In addition, the populations present in the whey powder-stimulated community were different than those observed during the sodium lactate-stimulated community. These data suggest that different populations were responsible for utilization of the whey powder than for the utilization of lactate. *Dehalococcoides*, the indicator

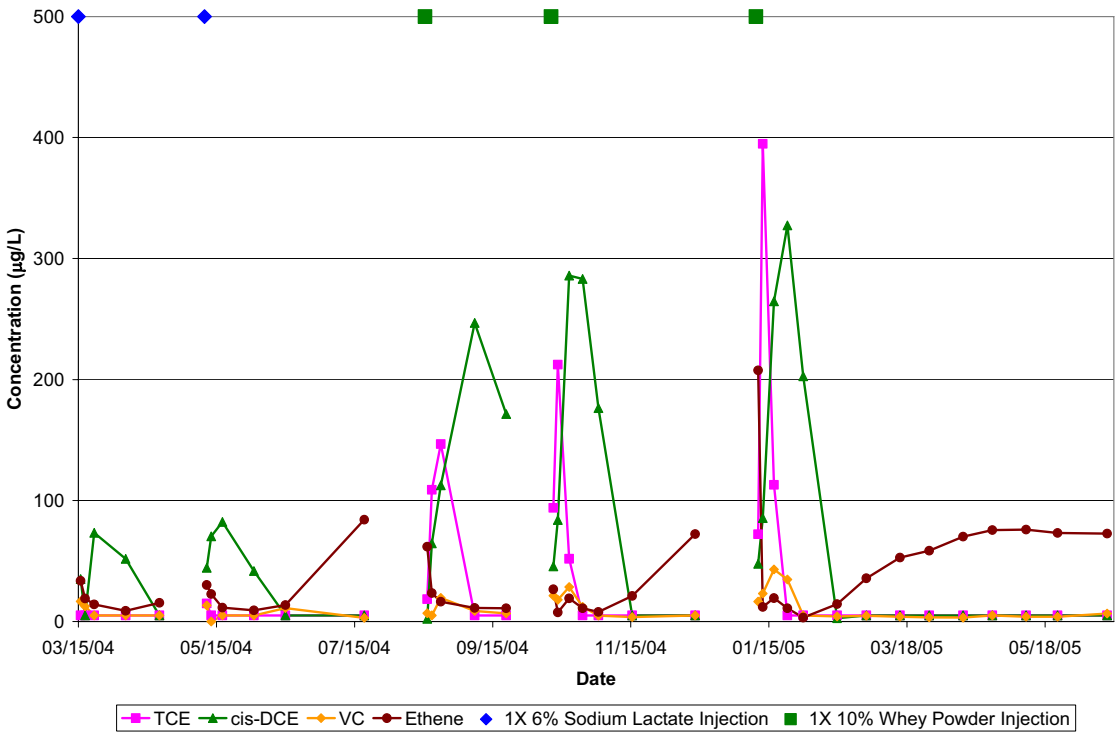

Figure 2-6. Anaerobic reductive dechlorination parameters at TAN-25 during the alternate electron donor optimization.

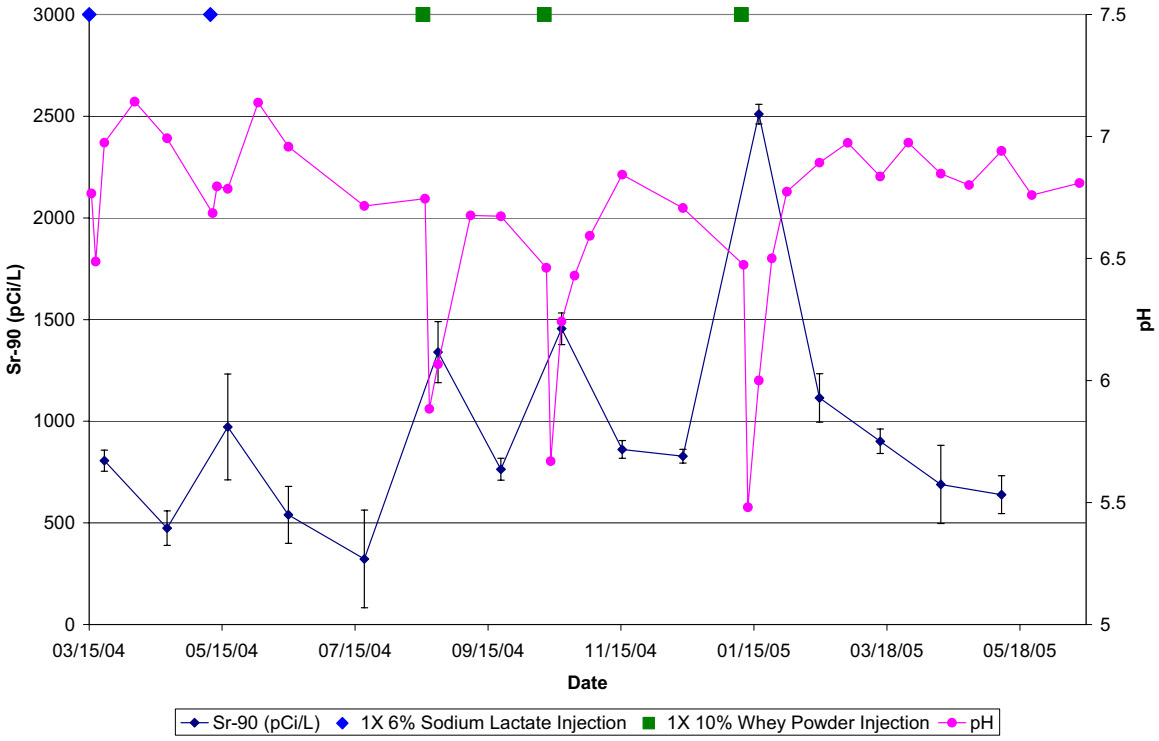

Figure 2-7. Sr-90 and pH at TAN-25 during the alternate electron donor optimization.

species for the ability of a community to completely degrade tetrachloroethene (PCE) to ethene was present at high numbers during both sodium lactate and whey powder injections. Concentrations were slightly lower after whey powder injections than after sodium lactate injections. Although these data show significant differences in the microbial community stimulated by whey powder compared to sodium lactate, both structures supported growth and activity of contaminant-degrading microbes, and thus support efficient ARD.

- **Cost—**Comparisons of costs, based on the total amount of electron donor injected, the concentration of TCE degraded over time per unit of electron donor injected, the impacts of the electron donors to the remedial timeframe, and a comparison of the average costs based on ARD efficiency, is included in Attachment A. During the AED optimization, the cost of whey powder was $2,750 for each injection and the cost of sodium lactate was $11,700 per injection. This cost comparison indicates that whey powder provides a significant cost savings of $8,950 per injection.

2.3 Conclusions

The AED Optimization Plan (Harris and Hall 2004) identified decision inputs to be used when comparing the effectiveness of sodium lactate and AED optimization results for whey powder. Comparisons of the decision inputs are summarized in Table 2-1.

Table 2-1. Comparison results for sodium lactate and whey powder injections.

Decision Input	Sodium Lactate	Whey Powder
Electron Donor Distribution	Cannot be effectively distributed at concentrations greater than 6% nominal concentration as a result of density-driven flow (INEEL 2000).	Can be effectively distributed at a 10% w/w concentration. Comparable volumes of a 10% w/w whey powder solution distributed higher concentrations of electron donor than 6% sodium lactate solution.
Electron Donor Utilization	Lower utilization rate of primary substrate; overall shorter longevity of secondary degradation products.	Higher utilization rate of primary substrate; overall greater longevity of secondary degradation products.
Geochemistry Parameters	Maintains methanogenic conditions.	Maintains methanogenic conditions. Reduction in pH observed following injections; however, pH rebounds to pre-injection levels within 2 to 3 weeks.
Anaerobic Reductive Dechlorination	Maintains complete dechlorination of dissolved TCE to ethene.	
Dissolution of TCE from the Residual Source	TCE dissolution from residual source.	Greater concentrations of TCE dissolved and degraded from the residual source over an injection cycle as compared to sodium lactate.

Table 2-1. (continued).

Decision Input	Sodium Lactate	Whey Powder
Radionuclide Concentrations	Sr-90 concentrations increase following each injection; however, concentrations return to pre-injection concentrations.	Greater increases in Sr-90 concentrations were observed following sodium lactate injections. Higher concentrations of Sr-90 are correlated with reductions in pH; however, when pH rebounds, Sr-90 concentrations return to pre-injection concentrations.
Microbial Community Health	*Dehalococcoides* present in higher concentrations; higher population diversity; similar number of active organisms; supports efficient ARD.	*Dehalococcoides* present in lower concentrations; lower population diversity; similar number of active organisms; supports efficient ARD.
Cost	During the AED optimization: - Unit cost = \$0.79/lb - Cost per injection = \$11,700.	During the AED optimization: - Unit cost = \$0.275/lb - Cost per injection = \$2,750. The use of whey powder as an electron donor at TAN will result in a cost savings of \$ \$8,950 per injection.

AED = alternate electron donor
ARD = anaerobic reductive dechlorination
TAN = Test Area North
TCE = trichloroethene

Based on the conclusions of the AED optimization, whey powder was recommended as the electron donor for future ISB injections based on:

- High concentrations of whey powder were effectively distributed over a large area resulting in efficient ARD of TCE to ethene.
- The whey-stimulated microbial community, although significantly different from the lactate-stimulated community, supported efficient ARD.
- Enhanced dissolution of TCE from the residual source into the aqueous phase was observed to a greater extent during a whey powder injection cycle as compared to a sodium lactate injection cycle, resulting in a greater rate of contaminant mass removal over time and a reduction in the remedial timeframe.
- Cost per injection using whey powder is significantly less than using sodium lactate.

3. SUMMARY OF IN SITU BIOREMEDIATION INITIAL OPERATIONS FROM JULY 2005 THROUGH SEPTEMBER 2005

This annual report provides a description of the AED optimization and a description of ISB activities for Fiscal Year 2005. Since the AED optimization was conducted from March 2004 through June 2005, activities performed during Fiscal Year 2005 that were included within the timeframe of the AED optimization are summarized in Section 2 and not repeated in this section. Therefore, this section details the remainder of the reporting period, which includes activities performed (Section 3.1) and results (Section 3.2) from July 2005 through September 2005.

3.1 Activities Performed

Activities performed from July 2005 through September 2005 are described in the following sections. This includes a detailed description of electron donor injection (Section 3.1.1), groundwater monitoring (Section 3.1.2), water quality instrument monitoring (Section 3.1.3), and waste management (Section 3.1.4).

3.1.1 Electron Donor Injection

The results of past injections into TSF-05 suggest that higher concentrations of electron donor are distributed to the lower screened interval at 265 to 305 ft bgs (TSF-05B) than to the upper screened interval at 180 to 244 ft bgs (TSF-05A). A packer system was installed in TSF-05 on July 12, 2005, in order to target electron donor injection to different vertical zones of the aquifer. The top of the packer was placed at approximately 245 ft bgs, just below the upper-screened interval. The objective of this placement was to allow injection of electron donor either above the packer (targeting the upper screened interval of 180 to 244 ft bgs) or below the packer (targeting the lower screened interval of 269 to 305 ft bgs). A gravel pack that surrounds the casing of the TSF-05 well, however, could serve as a flow path between the vertical zones separated by the packer. A diagram of the TSF-05 packer is shown in Figure 3-1.

In order to evaluate electron donor distribution using the packer-system, a whey powder injection was performed into TSF-05 in the upper-screened interval of the packer on July 13, 2005, in accordance with the ISB Operations and Maintenance Plan (DOE-ID 2004b). The injection consisted of a 1X (approximately 12,000 gal), 10% whey powder injection. Details of the injection include:

- Injection of 10,000 lb of whey powder (feed grade whey powder used for the injection consisted of 70 to 75% lactose, 10 to 13% protein, and 7 to 13% ash)
- Total volume of injected whey powder solution of 13,218 gal
- Resultant whey concentration of 9.88% (w/w)
- Combined injection flow rate of 36.0 gal per minute
- A potable water flush of 1,860 gal following the injection.

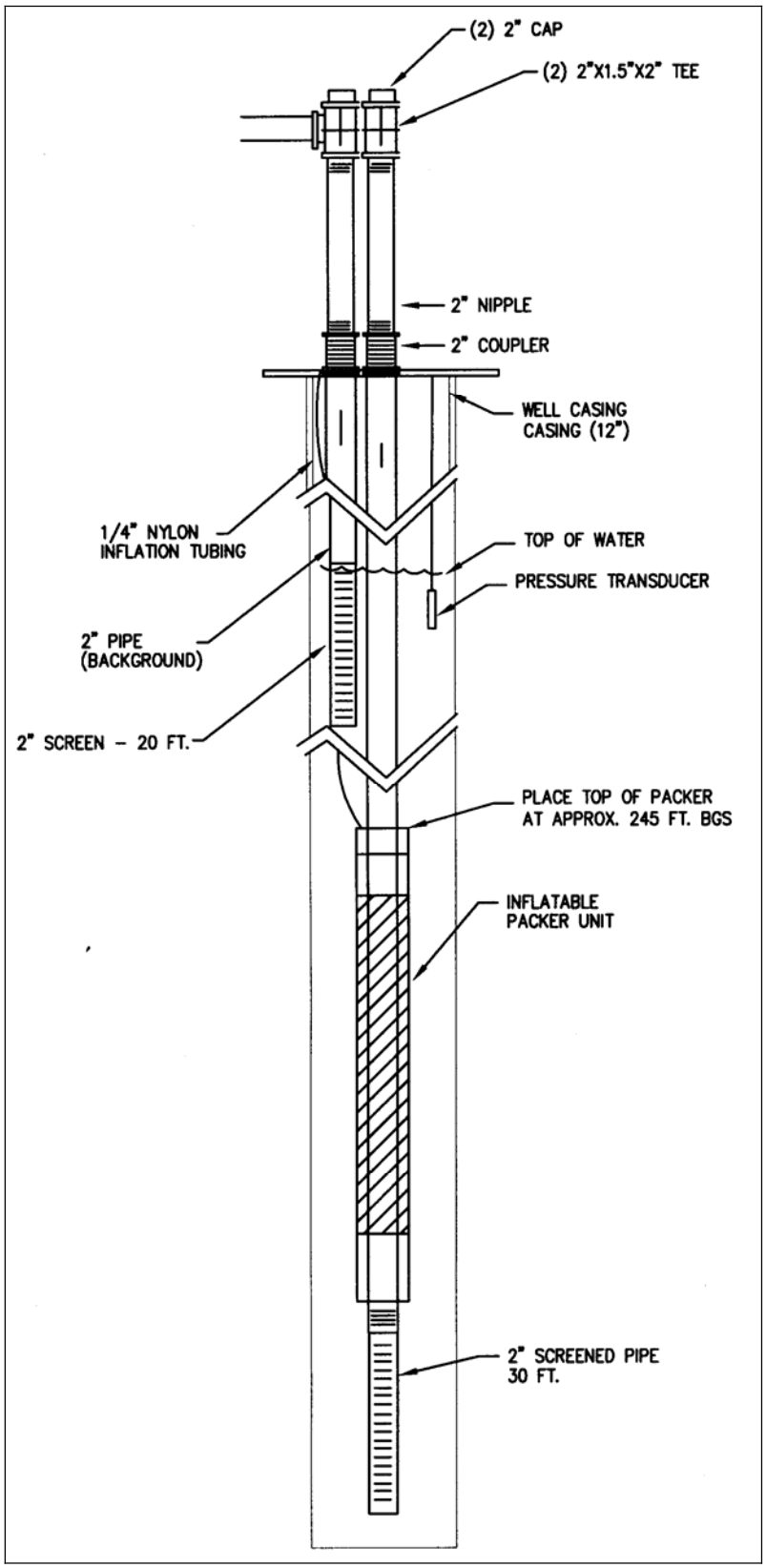

Figure 3-1. Diagram of TSF-05 packer.

3.1.2 Groundwater Monitoring

From July 2005 through September 2005, groundwater monitoring was conducted on a monthly basis (July 18–19; August 15–16; and September 12–13) in accordance with the ISB Groundwater Monitoring Plan (INEEL 2003b). Wells sampled during this reporting period, the depths sampled for each well, and the distance to each well from TSF-05 are presented in Table 3-1.

Table 3-1. Wells sampled during the in situ bioremediation sampling events from July 2005 through September 2005.

Well	Depth Sampled (ft)	Distance from TSF-05 (ft)
TSF-05A[a]	235	0
TSF-05B[a]	270	0
TAN-25	218	26
TAN-26	389	50
TAN-27	235	318
TAN-28	240	260
TAN-29	253	513
TAN-30A	313	270
TAN-31	258	50
TAN-37A[a]	240	146
TAN-37B[a]	270	146
TAN-37C[a]	375	146
TAN-10A	233	179
TAN-D2	241	116
TAN-9	293	91
TAN-1859	250	92
TAN-1860	269	265
TAN-1861	239	246

a. Wells TSF-05 and TAN-37 are sampled at multiple depths. The letter following the well number is used to represent the depth.

Table 3-2 presents the details of each sampling event including sampling date, wells sampled, analyses performed, analytical method, and analysis location with further details provided in the Sampling and Analysis Plan (SAP) tables (Attachment B). The only addition to the SAP tables was collection of a microbiological analysis sample from TAN-25 on July 18, 2005. The only deviation from the SAP tables was that sampling conducted in July was performed on July 18–19, rather than the originally scheduled dates of July 11–12, 2005.

Table 3-2. Summary of in situ bioremediation groundwater monitoring events from July 2005 to September 2005.

Sampling Date	Wells Sampled[a]	Analyses Performed[b]	Analytical Method[c]	Analysis Location[d]
July 14, 2005	TSF-05A, TSF-05B	COD	Hach® Test Kit	ISB Field Laboratory
July 18–19 August 15–16 September 12–13, 2005	All ISB wells	Alkalinity, pH, ferrous iron, sulfate, COD, ammonia nitrogen, phosphate[e]	Hach® Test Kits	ISB Field Laboratory
	All ISB wells	VOCs E/E/M Electron donor	SPME GC-FID IC and GC-FID	IRC
	All ISB wells	Tritium	Liquid scintillation counting	Off-Site laboratory, General Engineering Laboratories, LLC
	TSF-05A, TSF-05B, TAN-25, TAN-26, TAN-31, and TAN-1859	Gamma screens	Gamma spectroscopy	INL Radiation Measurement Laboratory

a. All ISB wells include: TSF-05A, TSF-05B, TAN-25, TAN-26, TAN-27, TAN-28, TAN-29, TAN-30A, TAN-31, TAN-37A, TAN-37B, TAN-37C, TAN-10A, TAN-D2, TAN-1859, TAN-1860, TAN-1861, and TAN-9.
b. COD = chemical oxygen demand; VOCs (volatile organic compounds) = trichloroethene (TCE), tetrachloroethene (PCE), cis-1,2-dichloroethene (cis-DCE), trans-1,2-dichloroethene (trans-DCE), and vinyl chloride (VC); E/E/M = ethene, ethane and methane; electron donor = formate, acetate, propionate, lactose, isobutyrate, butyrate, isovalerate, valerate, hexanoate.
c. SPME = solid-phase microextraction; GC-FID = gas chromatography/flame ionization detector; IC = ion chromatography.
d. ISB Field Laboratory is located in TAN-1614; IRC = INL Research Center; off-Site laboratory = General Engineering Laboratories, LLC; Charleston, SC.
e. Ammonia nitrogen and phosphate were only measured during the July 2005 sampling event.

3.1.3 Water Quality Instruments

In situ water quality data from a subset of the ISB monitoring wells were measured using multi-parameter water quality instruments. Water quality instrument types included the TROLL® 9000E (In Situ, Inc.), miniTROLL (In Situ, Inc.), Hermit, CTD-Diver (Van Essen Instruments), and Hydrolab® (Hach Company).[a] These instruments measured temperature, depth, and specific conductance in groundwater in situ. Specific conductance data are used to monitor the distribution of electron donor, while water depth data are used to monitor mounding during electron donor injections. The TROLLs, Hydrolabs, and Diver are used to monitor multiple parameters, while the miniTROLL and Hermit are transducers and can only monitor depth.

a. References herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Government, any agency thereof, or any company affiliated with the Idaho Cleanup Project.

At the beginning of FY 2005, TROLL 9000Es were installed in TAN-28, TAN-30A, TAN-1861, TAN-37A, and TAN-37B; a miniTROLL was deployed in TAN-1859; a Hydrolab in TAN-1859; and a Hermit in TSF-05. On December 2, 2004, the TROLL was removed from TAN-1861. On December 15, 2004, the TROLL in TAN-37B was removed for repair. Therefore, the TROLL was removed from TAN-30A and placed in TAN-37B on December 22, 2004. On February 15, 2005, the TROLL in TAN-31 was withdrawn for repair and placed back into TAN-31 on May 16, 2005. On June 1, 2005, the TROLLs were removed from TAN-31, TAN-37A, and TAN-37B, and the Hydrolab was also removed from TAN-1859 for maintenance. These instruments were deployed back into the wells on June 14, 2005. On August 25, 2005, the TROLLs in TAN-37A and TAN-37B were removed for repair; and were not replaced during FY 2005. On September 28, 2005, the Hydrolab in TAN-1859 became detached from its cord while deployed in the well and has not been recovered.

3.1.4 Waste Management

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 USC § 9601 et seq.) wastes generated during ISB sampling activities are managed according to the requirements of the *Waste Management Plan for Test Area North Final Groundwater Remediation Operable Unit 1-07B* (INEEL 2002b, 2005). Waste generated during these activities could include contaminated wipes, sample bottles, personal protective equipment (e.g., gloves), sample residue from field analyses, sample rinsate, and purge water. Removal of solid and liquid wastes generated in the ISB Field Laboratory was coordinated with INL Waste Generator Services. The New Pump and Treat Facility was used to process unaltered sample rinsate and purge water following each sampling event.

3.2 Results

Results of the ISB Initial Operations activities from July 2005 to September 2005 are presented in this section. All groundwater monitoring data generated during FY 2005, with the exception of the water quality instrument data, have been uploaded into the INL Environmental Data Warehouse. Additionally, the data are replicated on a CD included with this report (Attachment B). Section 3.2.1 evaluates the distribution and degradation of the electron donor following the whey powder injection on July 13, 2005. Section 3.2.2 presents redox conditions, Section 3.2.3 evaluates ARD, and Section 3.2.4 discusses biological activity indicators. Finally, Section 3.2.5 presents radiological monitoring data and Section 3.2.6 summarizes quality assurance (QA) results.

3.2.1 Electron Donor Distribution and Degradation

This section describes the distribution and degradation of electron donor following the 1X 10% w/w whey powder injection on July 13, 2005. In general, whey powder is comprised of lactose and proteins that are anaerobically degraded to measurable concentrations of the VFAs butyrate, acetate, propionate, with minor production of the daughter products isobutyrate, isovalerate, valerate and hexanoate at TAN. The relative concentrations of the electron donor distributed to each well after injection are presented in Table 3-3. The COD and electron donor concentrations in all ISB wells are presented in Attachment B.

The results following the TSF-05 whey injection into the upper-extent of the aquifer on July 13, 2005, are similar to observations following previous injections into TSF-05 without the use of a packer. COD was observed the day after injection in both TSF-05A and TSF-05B at similar concentrations, indicating that electron donor was still transported to the lower extent of the aquifer. Electron donor was radially distributed to TAN-25, TAN-31, and TAN-1859. Elevated electron donor concentrations remained in all wells affected by the injection for at least one week, but were generally depleted to less than 100 mg/L by 1 month after the injection (Table 3-3) with the exception of TSF-05B, with persisting concentrations greater than 500 mg/L for 2 months after the injection.

Table 3-3. Electron donor data following the July 13, 2005, whey powder injection in TSF-05.

Well	Days After Injection	COD (mg/L)	Lactose (mg/L) Molar %	Acetate (mg/L) Molar %	Propionate (mg/L) Molar %	Butyrate (mg/L) Molar %	Isobutyrate (mg/L) Molar %	Isovalerate (mg/L) Molar %	Valerate (mg/L) Molar %
TSF-05A	2	16,200	NA	NA	NA	NA	NA	NA	NA
	6	3,996	34 0%	1,392 49%	746 21%	1,246 30%	7 0%	15 0%	7 0%
	33	96	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
	60	44	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
TSF-05B	2	12,276	NA	NA	NA	NA	NA	NA	NA
	6	18,216	459 0%	2,493 48%	545 8%	3,150 41%	9 0%	129 1%	9 0%
	33	2,430	0 0%	837 50%	312 15%	643 26%	91 4%	97 3%	41 1%
	60	783	0 0%	533 70%	166 18%	19 2%	46 4%	61 5%	15 1%
TAN-25 [a]	6	6,714	43 0%	2,072 46%	899 16%	2,406 36%	18 0%	30 0%	17 0%
TAN-31 [a]	6	6,318	111 0%	1,650 47%	967 22%	1,478 29%	11 0%	20 0%	6 0%
TAN-1859 [a]	6	2,166	33 0%	880 58%	699 37%	71 3%	4 0%	9 0%	0 0%
TAN-37A [a]	7	11	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
TAN-37B [a]	7	818	34 0%	46 58%	17 37%	51 3%	0 0%	0 0%	0 0%

NA indicates that these data are not available (i.e., these parameters were not measured on the given day).
COD = chemical oxygen demand
VFA = volatile fatty acid

a. COD and VFAs were below practical quantification limits for days 33 and 60 following the injection.

Electron donor was not distributed to TAN-37A, but low concentrations of VFAs (<100 mg/L total VFAs) were observed at TAN-37B. Although high COD (818 mg/L) was measured at TAN-37B following the July injection, the high concentrations observed were not corroborated with the VFA data, which suggested that 100 mg/L reached this location. By the Day 33 sample event, all COD and VFAs were depleted at TAN-37B.

Evaluation of the electron donor utilization rate after various injections is a fundamental part of optimizing injection strategies. An in-depth discussion of the calculation of utilization rate coefficients is provided in Attachment A. Briefly, the utilization rate coefficient is calculated using the first order decay model, plotting the natural log of the electron donor concentration versus time, and determining the slope of the line. The resulting first order COD degradation rate constants for the July 13, 2005 injection for the source area wells are shown in Table 3-4. The rate constants were calculated using the Day 2, 6, and 33 COD values for TSF-05A and TSF-05B, and the Day 6 and 33 COD values for TAN-25 and TAN-31.

Table 3-4. First order chemical oxygen demand degradation rate constants for July 13, 2005, injection in TSF-05.

Well	Decay Constant, k (day^{-1})	Previous Range Decay Constants, k (day^{-1})	
		Sodium Lactate	Whey Powder[a]
TSF-05A	0.15	0.03[b] - 0.18[c]	0.14 - 0.15
TSF-05B	0.07	0.04[d] - 0.14[e]	0.10 - 0.12
TAN-25	0.13	0.04[f] - 0.15[c]	0.12 - 0.14
TAN-31	0.15	0.08[f] - 0.18[g]	0.13 - 0.15

a. 1X 10% AED optimization

b. 1X 6% May 2000

c. 1X 6% November 2003

d. 1X 6% September 2001

e. 1X 6% January 2004

f. 4X 6% March 2002

g. 4X 3% October 2002

The COD decay constants for TSF-05A, TAN-25, and TAN-31 were comparable with decay constants observed after the previous whey powder injections (Table 3-4), suggesting that the utilization of the amended electron donor was comparable. The decay constant for TSF-05B, however, was slightly less than the decay constants previously observed for whey powder injections, suggesting that utilization at this location was lower than what had been observed previously.

3.2.2 Redox Conditions

For efficient ARD of TCE to ethene, redox conditions that support methane production are required. Methanogenic conditions are generally described by the absence of sulfate (and other electron acceptors including dissolved oxygen) and the presence of ferrous iron and methane. Results of redox parameters for all ISB wells are presented in Attachment B.

Methanogenic redox conditions generally describe locations within the biologically active zone where electron donor is distributed as a result of injections into the residual source area. TSF-05A, TSF-05B, TAN-25, TAN-31, and TAN-1859 all have depleted oxygen and sulfate (0 mg/L), and elevated ferrous iron (between 1 to 10 mg/L). In addition, persistent, high concentrations of methane (10,000 μg/L) are observed at these locations.

Redox conditions in wells located outside of the biologically active area were generally more aerobic with sulfate concentrations of approximately 20 to 50 mg/L. In addition, dissolved iron concentrations were generally low (<2 mg/L) in these wells, with the exception of TAN-26 and TAN-37C (2 to 3.3 mg/L) and TAN-D2 (3 to 4 mg/L). Methane concentrations remained high (generally >10,000 μg/L) in deep wells TAN-26, TAN-37C, and TAN-30A, and nominally high (greater than 5,000 μg/L) in TAN-09, TAN-10A, TAN-1860, and TAN-1861. In addition to relatively low concentrations of methane, high sulfate concentrations (40 to 50 mg/L) at these locations suggest that the methane present is transported to these locations rather than generated as a result of methanogenesis. The deeper part of the aquifer continues to maintain extremely reducing conditions (TAN-26 and TAN-37C), as evidenced by the methane production and depleted sulfate levels.

3.2.3 Anaerobic Reductive Dechlorination

Efficiency of ARD is measured by examining the relative concentrations of TCE and reductive daughter products cis-DCE, VC, and ethene. The percent of each compound's total contribution on a molar basis at each well within the biological active area is presented in Figures 3-2 and 3-3. Following the injection into TSF-05, TCE is liberated from the source material and is seen as an initial spike that comprises approximately 25% of the total chlorinated compounds present (as TCE, cis-DCE, VC, and ethene) in TSF-05A and TSF-05B, and 69 to 91% in TAN-25 and TAN-31. TAN-1859 was the only location where TCE accounted for <10% of the chlorinated compounds present one week after the injection. By 1 month after the injection, a high percentage of TCE was converted to ethene, representing between 70 and 99% of the total molar percentage of ARD compounds present in TSF-05A, TSF-05B, TAN-25 and TAN-31.

Trans-DCE is also present within the ISB residual source area at relatively high concentrations. This compound, however, is generally not considered to be biologically produced or degraded via ARD at TAN. Percent contribution of trans-DCE to total chlorinated compound concentration on a molar basis is as follows: TSF-05A—15% 1 week and 16% 1 month after the injection; TSF-05B—15% 1 week and 21% after 1 month; TAN-25—17% 1 week and 61% after 1 month; TAN-31—20% 1 week and 82% after 1 month; and TAN-1859—64% 1 week and 60% after 1 month. The ARD parameters in all ISB wells are presented in Attachment B.

3.2.4 Biological Activity Indicators

Alkalinity and pH are monitored in all ISB wells as two parameters indicative of biological activity in the aquifer. Alkalinity continues to remain high (1,000 to 4,000 mg/L as $CaCO_3$) in all source areas (TSF-05A, TSF-05B, TAN-25, TAN-31, and TAN-1859) and deep (TAN-26 and TAN-37C) wells. Wells outside the direct influence of TSF-05 injections have lower alkalinity levels, ranging from 200 to 700 mg/L as $CaCO_3$. Following the onset of bioremediation activities as a part of the 1999 field evaluation, alkalinity increased for a period of approximately 4 years, with the highest concentrations observed in 2003. Over the past 2 years, however, a general decline in alkalinity levels, starting around the first part of 2004 in TSF-05A, TSF-05B, TAN-25, and TAN-31 was observed. Since whey powder injections began, however, alkalinity appears to have stabilized at TSF-05A and TAN-25 (Figure 3-4).

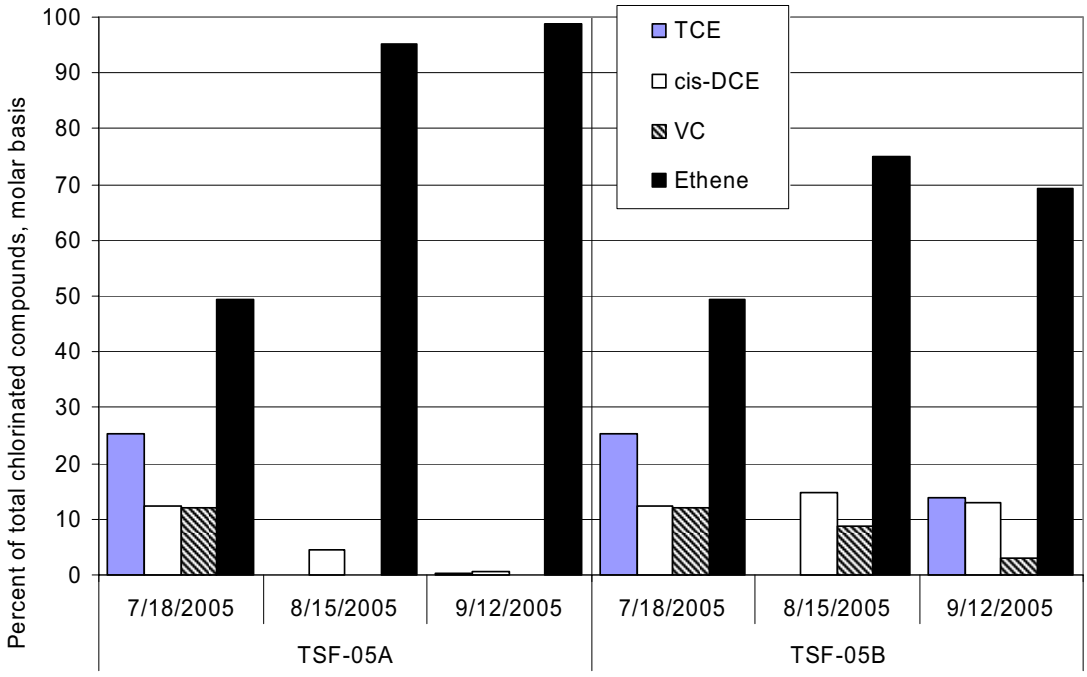

Figure 3-2. Percent trichloroethene, cis-DCE, vinyl chloride, or ethene of total chlorinated compounds (molar basis, excluding trans-DCE) in TSF-05A and TSF-05B. The whey powder injection was performed on July 13, 2005.

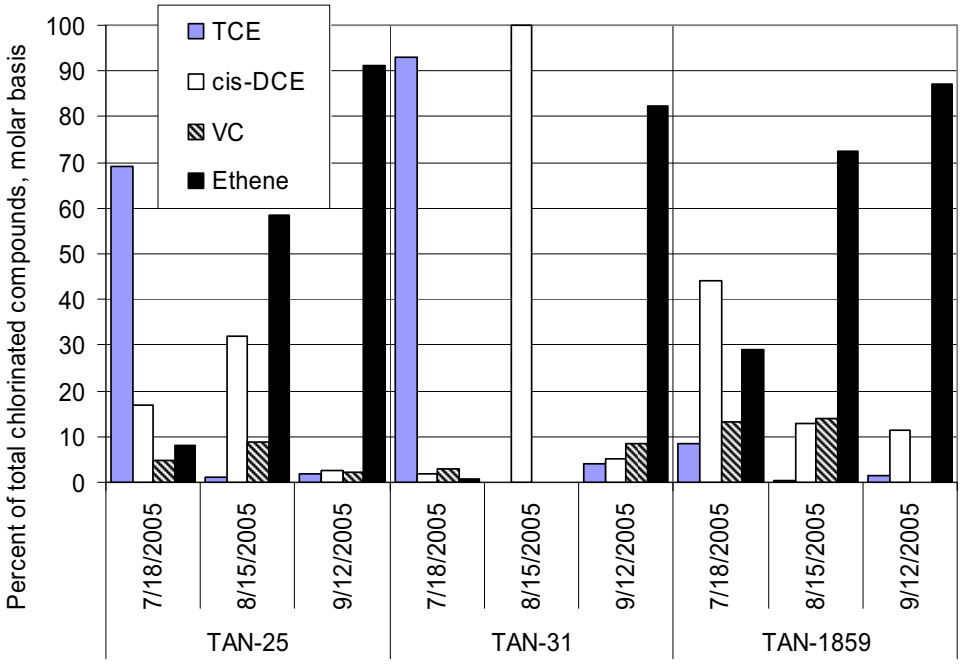

Figure 3-3. Percent trichloroethene, cis-DCE, vinyl chloride, or ethene of total chlorinated compounds (molar basis, excluding trans-DCE) in TAN-25, TAN-31, and TAN-1859. The whey powder injection was performed on July 13, 2005.

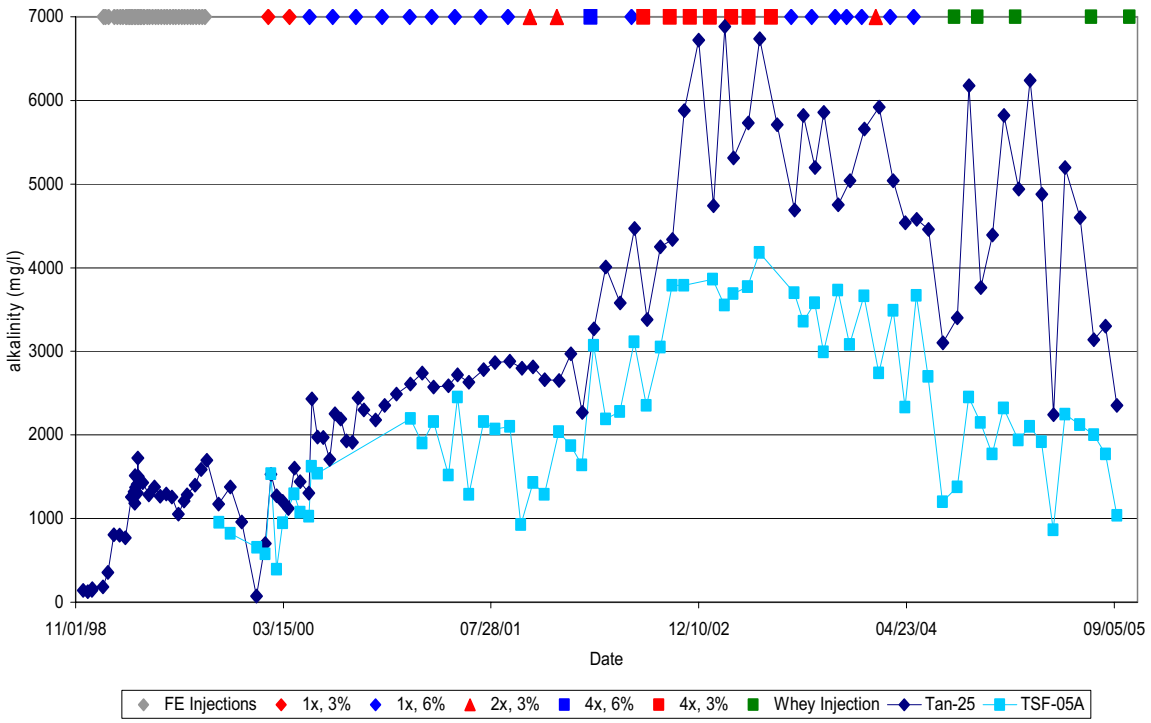

Figure 3-4. Alkalinity in TAN-25 and TSF-05A.

One significant difference between whey powder and sodium lactate is the drop in pH observed following whey powder injections. The primary component of whey powder, lactose, is rapidly fermented resulting in the rapid generation of VFAs, which lower pH. After the July 13, 2005, whey powder injection, pH dropped to as low as 5.0 and 5.5, but rebounded 1 month following the injection to 6.2 and 6.7 at TSF-05B and TSF-05A, respectively. Bioactivity indicators from all ISB wells are presented in Attachment B.

3.2.5 Radiological Monitoring

Analysis of groundwater samples for tritium and Sr-90 is conducted as part of the OU 1-07B remedy. Tritium is monitored on a monthly basis since tritium can be indicative of changes in source release rates or other hydrogeologic changes. Tritium concentrations collected from July 2005 through September 2005 do not appear to correlate with the injection and remained relatively stable and below MCLs. Collection of strontium-90 is conducted as part of Monitored Natural Attenuation activities. Therefore, all Sr-90 results are included in MNA Annual Reports, with the exception of the additional Sr-90 samples collected during the AED optimization at TAN-25 (Figure 2-7). Results and conclusions of the radiological monitoring performed during the AED optimization are included in Attachment A, and radionuclide data from all ISB wells are presented in Attachment B.

3.2.6 Quality Assurance

In situ bioremediation data quality is assessed by collecting and analyzing samples to monitor precision, accuracy, and completeness for all groundwater parameters monitored. Specifically, precision is evaluated through analysis of duplicate samples; accuracy is evaluated through the performance of standards, standard additions, matrix spikes and matrix spike duplicates (MS/MSDs), and blanks; and completeness is monitored through comparison of samples planned versus samples collected.

General quality assurance (QA) requirements are established in the *Quality Assurance Project Plan for Waste Area Groups 1, 2, 3, 4, 5, 6, 7, 10, and Deactivation, Decontamination, and Decommissioning* (DOE-ID 2004c). Specific accuracy, precision, and completeness requirements for this reporting period are defined in the *In Situ Bioremediation Remedial Action Groundwater Monitoring Plan for Test Area North, Operable Unit 1-07B* (INEEL 2003b) and supporting documents.

A summary of the QA data for FY 2005 (October 2004 through September 2005) are shown in this section. Details of QA data results collected during the AED Optimization are presented in Attachment B. Details of QA data collected during the remainder of FY 2005 (July 2005 through September 2005) also are included in Attachment B. The ISB performance monitoring data are generated at the following three laboratories:

- **In Situ Bioremediation Field Laboratory**—Performance monitoring data are generated at the ISB Field Laboratory for COD, alkalinity, sulfate, iron, and pH. These data are used as a general indicator of changes in geochemistry in and around the TAN hot spot. Technical procedure (TPR) -166, "In Situ Bioremediation Field Laboratory Procedure" lists the sample type and frequency of collection for all QA monitoring, in addition to the accuracy and precision levels required.

- **INL Research Center Laboratory**—The INL Research Center (IRC) Laboratory performs screening level analyses for VOCs, dissolved gases, and electron donor constituents. The IRC laboratory is required to analyze field duplicates and blanks and to perform MS/MSD analyses for quality control. In addition, the lab is required to analyze certified performance evaluation (PE) standards once a month with the groundwater samples submitted to the IRC laboratory.

- **Off-Site Laboratory**—Semi-annual split samples were sent to off-Site laboratories for definitive confirmation of VOC concentrations. Samples collected to fulfill this requirement during FY 2005 were collected in November 2004 and June 2005.

Quality assurance data collected during this reporting period were to be used to monitor performance of ISB in order to determine whether operational changes were required. Table 3-5 shows the FY 2005 QA results in comparison to the FY 2004 results. In general, the FY 2005 QA results are similar or better than the FY 2004 results. No operational changes are recommended based on the QA results.

Table 3-5. Quality assurance results for Fiscal Year 2005 and comparison to results for Fiscal Year 2004.

		FY 2004 QA Results		FY 2005 QA Results	
Accuracy	Standards (percent within acceptable range)	COD	38%	COD	71%
		Sulfate	94%	Sulfate	86%
		Iron	85%,	Iron	100%
		Phosphate	100%	Phosphate	100%
		Ammonia	75%	Ammonia	67%
	Standard Addition (percent within acceptable range)	Sulfate	100%	Sulfate	95%
		Phosphate	100%	Phosphate	100%
		Alkalinity	94%	Alkalinity	97%
		Ammonia	100%	Ammonia	100%
	Splits (percent of samples with <25% RPD)	TCE	75%	TCE	100%
		trans-DCE	83%	trans-DCE	100%
		cis-DCE	33%	cis-DCE	36%[a]
		VC	45%	VC	20%[a]
	PE Samples	For the IRC, the majority of samples fell within the accepted performance limits for both low- and high-range VOC samples. For the off-Site laboratory, all results fell within the accepted performance limits.		For the IRC, the majority of samples fell within the accepted performance limits for both low- and high-range VOC samples. For the off-Site laboratory, all results fell within the accepted performance limits.	
	Blanks	For the blanks collected during this reporting period, no significant detections were reported.		For the blanks collected during this reporting period, no significant detections were reported.	
	MS/MSD Samples	For the IRC, the majority of samples met the target percent recovery requirements. For the off-Site laboratory, all of the target percent recovery requirements were met for TCE.		For the IRC, the majority of samples met the target percent recovery requirements. For the off-Site laboratory, 75% of the target percent recovery requirements were met for TCE.	
Precision (percent samples <25% RPD)		IRC	100%	IRC	100%
		Off-Site	80%	Off-Site	80%
Completeness		99.9%		100%	

COD = chemical oxygen demand
DCE = dichloroethene
FY = fiscal year
IRC = INL Research Center
MS/MSD = matrix spike/matrix spike duplicate
PE = performance evaluation
QA = quality assurance
RPD = relative percent difference
TCE = trichloroethene
VC = vinyl chloride
VOC = volatile organic compound

a: Average cis-DCE and VC concentrations for the off-Site laboratory was 22.3 and 8.8 µg/L, respectively, and for the IRC concentrations were 25.1 and 10.6 µg/L. Variability in low numbers results in relatively high RPDs.

4. DISCUSSION

This section discusses the results of data collected during the AED optimization and FY 2005 in a historical context. The purpose of this discussion is to evaluate the whey powder injections with other ISB injection strategies conducted over time during ISB Operations, in the context of achieving the goal of source remediation. Ultimately, a recommendation for optimizing the injection strategy using whey powder will be developed by evaluating several parameters that are essential to the success of bioremediation, and may be either mutually symbiotic, unaffected, or detrimental to each other including: (1) electron donor distribution, (2) enhanced dissolution of TCE from the residual source, (3) efficient ARD, and (4) cessation of flux from the residual source to downgradient locations. Comparison of electron donor injections (Section 4.1), status of source remediation (Section 4.2), and an injection strategy optimization plan for enhanced electron donor distribution (Section 4.3) is discussed.

Since the start of ISB operations in 1999, significant progress has been made toward achieving remediation goals. In the residual source area, electron donor has been effectively distributed radially approximately 100 ft, resulting in stimulation of biological activity and reduction in redox conditions. Within this biologically active area, complete ARD of TCE to ethene was achieved and is maintained, and enhanced dissolution of TCE from the residual source material to the aqueous phase where it is efficiently degraded has been demonstrated (INEEL 2002a; INEEL 2003a; Armstrong et al. 2004; and Macbeth et al. 2005). Although contaminants are effectively degraded within the biologically active area, as stated in the ISB Remedial Action Work Plan (DOE-ID 2004a), Initial Operations will be complete when VOC concentrations at TAN-28 and TAN-30A remain below the MCLs for a period of 1 year.

Optimization Operations will begin following completion of the Initial Operations phase. The goal of Optimization Operations will be to maintain adequate electron donor distribution in the residual source area to cut-off flux of VOCs in the crossgradient direction. Optimization Operations will be complete when VOC concentrations at TAN-1860 and TAN-1861 remain below MCLs for a period of 1 year.

4.1 Results of Historical Injections

To reach the Initial and Optimization Operations objectives, electron donor must be distributed throughout the entire hot spot in order to degrade the residual source and cut off flux to downgradient (TAN-28 and TAN-30A) and crossgradient (TAN-1860 and TAN-1861) locations. While past injections into TSF-05 have resulted in significantly decreased TCE concentrations in the hot spot, data collected from monitoring wells surrounding the hot spot indicate that the biologically active zone around TSF-05 does not presently encompass the entire residual source area. As a result, TCE concentrations in TAN-28 have continued to increase gradually over the past 2 years due to the continued downgradient flux of VOCs from the residual source area, although the concentrations are well below historical TCE concentrations of approximately 3,000 μg/L in 1994. In addition, TCE persists at TAN-30A, although concentrations appear to be declining over time.

In order to evaluate the injection strategy implemented during the AED optimization and during FY 2005 relative to historical injections, all historical injection strategies that occurred between January 1999 and September 2005 were divided into five separate phases. The first four phases are based on changes in the volume and frequency of sodium lactate injections, while the fifth phase is based on an amendment change from sodium lactate to whey powder. For the purposes of this evaluation, the five phases are as follows:

- Phase 1—Weekly sodium lactate injections (January 1999–September 1999)

- Phase 2—Bimonthly 1X (12,000 gal) sodium lactate injections (February 2000–January 2001)
- Phase 3—Bimonthly 4X (48,000 gal) sodium lactate injections (March 2002–June 2003)
- Phase 4—Bimonthly 1X sodium lactate injections (July 2003–May 2004)
- Phase 5—Variable frequency 1X whey powder injections (August 2004–Present).

In order to design an injection strategy that would achieve the goals of the Initial and Optimization Operations phases, an evaluation of how the different injection phases affected contaminant concentrations at downgradient locations was performed. To date, contaminant and geochemical data collected during the first four injection phases illustrate distinct chemical signatures and show distinctly different contaminant concentration trends over time in monitoring wells TAN-28 and TAN-37A (Sections 4.1.1 and 4.1.2). The effects of the fifth injection phase (whey powder injections) have not reached these monitoring wells at this time; however, the effects should begin to appear in monitoring data over the next year as groundwater impacted by whey powder injections travels to these locations. TCE and tritium data at the two axial downgradient wells, TAN-28 and TAN-37A, are used to assess the impacts of the different injection strategies (Section 4.1.1).

4.1.1 Trichloroethene Response to Historical Injections at TAN-28 and TAN-37A

Figure 4-1 illustrates the TCE concentration trends observed at TAN-28 and TAN-37A during the five injection phases described in Section 4.1. As an aid to interpretation, the injection history shown at the top of Figure 4-1 has been offset in time so that the injection phase is correlated to the subsequent response in contaminants at these locations (as based on an analysis of travel time from TSF-05 to TAN-28). The travel time from TSF-05 to TAN-28 was estimated based on the first arrival of the biogeochemical signature to these locations after the initial sodium lactate injections performed during the field evaluation. This travel time was estimated to be approximately 10 months. The time shift on Figure 4-1 represents 12 months because sampling began in November 1998 and the first sodium lactate injection was performed in January 1999. During the first 12 months of the ISB program, data collected at TAN-28 represent TCE concentrations prior to sodium lactate injections. This time period is referred to as “background” and discussed in more detail in Section 4.1.1.1. Following this initial 12-month period, substantial changes in contaminant concentrations were observed at these locations.

Contaminant concentrations observed at TAN-37A in response to sodium lactate injections have declined significantly over the course of ISB operations. Overall, the most striking feature in Figure 4-1 is the continued decreasing trend in TCE concentrations at TAN-37A and the generally increasing trend in concentration at TAN-28. The second most striking feature is that when the contaminant concentration response is adjusted for travel time to the two locations, the overall biogeochemical response to injection strategies at each well is close to contemporaneous, even though the wells are separated by approximately 125 ft and a theoretical 7- to 12-month groundwater travel time between the wells. The following sections summarize these TCE trends as they relate to an evaluation of changes in operations injection strategy.

4.1.1.1 Background. Data collected at TAN-37A and TAN-28 during the first 12 months (November 1998 through November 1999) represent conditions created by operation of the Groundwater Treatment Facility (GWTF) from 1995 through 1998. The combination of multiple source removal activities from 1990 to 1998, and intermittent GWTF operations from 1995 to 1998, resulted in a reduction of TCE concentrations in the source area until termination of GWTF operations in 1998. The TCE concentrations in TAN-37A and TAN-28 measured from the beginning of the ISB field evaluation in November 1998 through September 1999 were essentially the same, fluctuating around 800 μg/L (average TCE at TAN-28 was 797 μg/L and median was 792 μg/L; average TCE at TAN-37A was

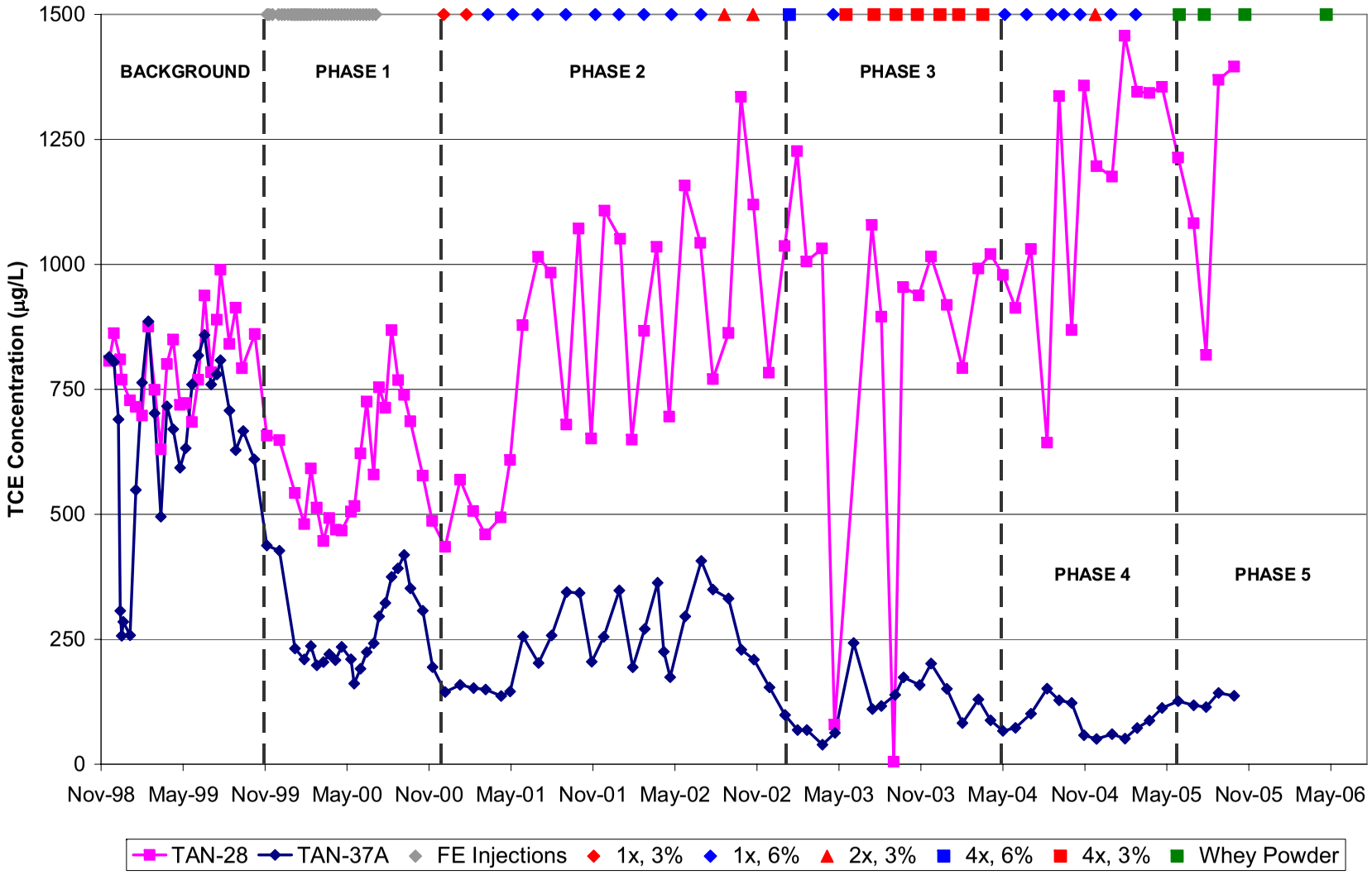

Figure 4-1. Trichloroethene concentration trends in TAN-28 and TAN-37A.

649 μg/L and median was 702 μg/L). The processes contributing to the variation seen in this background data are predominantly related to the effects of the GWTF and transport of TCE-contaminated groundwater out of the source area prior to initiation of the ISB field evaluation. An interesting observation is that TCE concentrations during this time are essentially the same in both wells. This may be indicative of "equilibrium" conditions along the flow paths to TAN-37A and TAN-28 prior to arrival of water carrying the signature of ISB biogeochemical transformations. This similarity of concentration during the background phase will be an important factor in evaluation of the different contaminant trends seen during the 6 years of active ISB treatment.

4.1.1.2 Phase 1: Weekly Sodium Lactate Injections. The injection strategy implemented during the ISB field evaluation may be generally categorized as weekly injections of sodium lactate solution. The volume and concentration of the amendment varied. The following injections were performed, in this order, during the ISB field evaluation:

1. Three 300-gal, 60% lactate

2. Four 600-gal, 30% lactate

3. Fourteen 1,500-gal, 6% lactate

4. Seven 3,000-gal, 6% lactate

5. Fourteen 6,000-gal, 3% lactate.

The field evaluation injection strategy was frequent enough that it could be considered a "single" injection relative to groundwater flow through the system. Sufficient amendment was injected to create a biologically active anaerobic zone that resulted in enhanced dissolution and subsequent degradation of TCE. The arrival of this biogeochemical fingerprint (i.e., declining TCE, methanogenic redox conditions) at TAN-28 and TAN-37A forms the basis for an estimate of effective travel time between TSF-05 and TAN-37A/TAN-28. Figure 4-1 demonstrates the injection operations strategy, time-shifted to match first arrival of the field evaluation fingerprint at TAN-37A/TAN-28. This estimated time shift is used in the following sections to facilitate an evaluation of previous injection strategies and the resultant effect seen at downgradient monitoring locations.

The primary result of the Phase 1 injections was to establish that a TCE biodegrading reactive zone could be established through the addition of sodium lactate as an electron donor (DOE-ID 2000; INEEL 2000). The frequent injection strategy resulted in a steady decline of TCE concentrations followed by production of ethene and resulted in significant buildup of lactate fermentation products in wells directly impacted by electron donor injections. The final operational activity in Phase 1 was to discontinue sodium lactate injections to allow the system to utilize this accumulated secondary electron donor in the source area. As this donor was utilized, TCE concentrations again fell to the lowest levels and ethene concentrations increased to the highest levels observed during the field evaluation in the source area. Therefore, this phase characterizes the development of the biologically active area within which TCE concentrations are depleted to below MCLs.

The time-shifted TCE concentrations at TAN-28 and TAN-37 show a declining trend during the field evaluation sodium lactate injections with concentrations dropping to below 500 μg/L at TAN-28 and 250 μg/L at TAN-37A. During the period of no lactate injections, however, concentrations rebounded to concentrations observed during the background phase. These data suggest that while the cessation of sodium lactate injections within the biologically active zone resulted in greater ARD efficiency, more frequent injections resulted in reduced VOC flux to downgradient locations.

4.1.1.3 Phase 2: Bimonthly 1X Sodium Lactate Injections.

The injection strategy implemented during Phase 2 may be generally categorized as bimonthly injections of 12,000 gal, 6% sodium lactate. A distinct change in the overall TCE concentration trend was observed with the onset of Phase 2 bimonthly injections. Figure 4-1 shows distinct and reproducible concentration fluctuations of approximately 400 μg/L between sampling events at TAN-28, as well as a TCE concentration trend that is generally increasing. Similarly, the fluctuated pattern was observed at TAN-37A, although to a much lesser extent, with TCE concentration fluctuations closer to 100 μg/L between sampling events. The time-shifted injection frequency across the top of the figure suggests that the timing of the variations may correspond to the roughly 10-month groundwater travel time from TSF-05 to TAN-28. It is possible that the higher frequency variations observed in Phase 2 are a direct response to individual bimonthly 1X, 6% sodium lactate injections. These data suggest that the larger volume injections that occurred during this injection phase resulted in substantial and reproducible spikes in TCE concentrations at TAN-28 and TAN-37A. This suggests that while the injections increased the effective area of the biologically active zone, this injection strategy did not reach all source material along the flow path to TAN-28 and TAN-37. In addition, the spikes in TCE concentrations observed in response to the injections may be due to a mild pressure pulse created during the injections that enhance dissolution of TCE from the source material outside of the sodium lactate distribution zone.

In contrast to the general trend in TCE concentrations seen at TAN-28, the trend observed at TAN-37A is generally decreasing with smaller amplitude short-term fluctuations. This distinction is quite important to an interpretation of the electron donor distribution resulting from past injection strategies. The important point is that the diverging trends in TAN-28 and TAN-37A provide important observational data on the effects of single well injection and the resulting ISB performance effects at axial downgradient monitoring wells. These data suggest that the larger volume injections resulted in maintenance of a biologically active area that is near TAN-37A, resulting in a reduction in the contaminant flux to this location compared to background levels. In contrast, contaminant concentrations at TAN-28 rebounded to near background levels, and then fluctuated to even higher concentrations. This suggests that separate and distinct flow paths connect each well to different regions of the source area, and that more unimpacted source is along the flow path between TSF-05 and TAN-28 than between TSF-05 and TAN-37A. This observation can be further assessed with regard to the Phase 3 injections and, if validated, will be an important consideration in evaluation of future operations strategies even though TAN-28 is located 125 ft downgradient of TAN-37. This theory will be validated based on continued observation at these wells over the next few months as the effects of the whey powder injections are expected to be observed in these wells. Additionally, TAN-29, which is even further downgradient, will serve as another monitoring well for observation of these effects.

4.1.1.4 Phase 3: Bimonthly 4X Sodium Lactate Injections.

The injection strategy implemented during Phase 3 may be generally categorized as bimonthly injections of 48,000-gal, 3% sodium lactate. Initially, there was a single 48,000-gal, 6% lactate injection followed 3 months later by a 12,000-gal, 6% lactate injection. Bimonthly injections of 48,000-gal, 3% lactate started 1 month after the 12,000-gal event and continued for 12 months. The general effect of the 4X injections at TAN-28 was to stabilize TCE concentrations at approximately 900 μg/L. It is notable that the short-term variability is less than that observed in Phase 1. There are two anomalously low data points at the beginning of Phase 3. The operational event that caused this decline cannot be clearly identified due to the uncertainty in estimated time lag between injection and an observed effect at a downgradient monitoring well location. The drop in concentration is quite dramatic and appears real (rather than associated with lab error) when compared to 5 years of analytical data, because a more muted response is seen in TAN-37A and TAN-27 data (Attachment B).

The response to larger volume injections is not as pronounced at TAN-37A during Phase 3, but the general declining trend seen in Phase 2 continues. This further supports the separate flow path hypothesis

developed from review of Phase 1 and 2 data. The TCE concentration at TAN-37A during Phase 2 was approximately 200 µg/L and approximately 100 µg/L during Phase 3. It is difficult to associate this decline in concentration with either the 4X injections or the general effectiveness of TCE degradation within the reactive zone. Continuation of the declining trend does suggest that electron donor distribution has encompassed most of the source material along the flow path from TSF-05 to TAN-37A, and that ISB operations continue to decrease the overall source strength near this location.

The 4X injection strategy using aerobic potable water had a noticeable and detrimental effect on maintaining efficient TCE degradation near TSF-05, as indicated by persisting cis-DCE concentrations at TSF-05B (Armstrong et al. 2004). Consequently, the large volume injections were discontinued and 12,000-gal, 6% injections resumed while the alternate electron donor optimization was planned and evaluated.

4.1.1.5 Phase 4: Bimonthly 1X Sodium Lactate Injections. Based on operational recommendations, Phase 4 consisted of resuming bimonthly 12,000-gal, 6% lactate injections. During this phase, two injections were performed into TAN-1859. A 12,000-gal, 6% lactate injection was performed on December 1, 2003, and a 24,000-gal, 3% lactate injection was performed on February 9, 2004. In general, it appears that TCE concentrations in TAN-28 increased to approximately 1,200 µg/L and the short-term variability seen in Phase 2 returned. TCE in TAN-37A continued to decline on the same trend seen in the earlier phases. The difference between the TCE trends observed in TAN-37A/TAN-28 over 5 years of monitoring suggest there are quite real differences in the flow paths that connect these monitoring wells to the source area.

4.1.1.6 Phase 5: Variable Frequency 1X Whey Powder Injections. Four 12,000-gal, 10% whey powder injections were performed during Phase 5. The first whey powder injection was performed on August 16, 2004. Timeframes between injections were 2 months (the second injection was performed on October 11, 2004), 3 months (the third injection was performed on January 10, 2005), and 6 months (the fourth injection was performed on July 12, 2005). The August 2004, October 2004, and January 2005 injections were conducted as part of the AED optimization. Although initial results of the whey powder injections show a decrease in TCE at TAN-28, there has not been sufficient travel time at present to clearly draw any conclusions regarding the effects of variable frequency whey injections performed during Phase 5. At TAN-37A, TCE concentrations were fairly stable at approximately 100 µg/L.

4.1.2 Tritium Response to Historical Injections at TAN-28 and TAN-37A

The significantly different TCE trends seen in TAN-28 and TAN-37A suggest that there are distinctly different flow paths from the residual source area to each of these wells. If the separate flow path hypothesis is true, the data would indicate that electron donor is being effectively delivered to more of the source area located along the flow path to TAN-37A than along the flow path to TAN-28. Evaluation of tritium data provides an independent assessment of the separate flow path hypothesis. Tritium concentration will not be affected by changes in redox conditions and can be expected to move as a conservative tracer showing a declining trend resulting from radioactive decay.

Figure 4-2 presents tritium data for both TAN-28 and TAN-37A. The travel-time offset injection phases are plotted along the top for easy reference to Figure 4-1. The solid line represents the trend that would be expected if radioactive decay were the only process affecting tritium concentrations. The most remarkable feature of this plot is that the TAN-37A tritium trend is declining faster than would be predicted, and the TAN-28 trend has slightly increased. The increase in tritium concentrations at TAN-28 suggests that flux of tritium has increased over time to TAN-28, which is consistent with the increase in

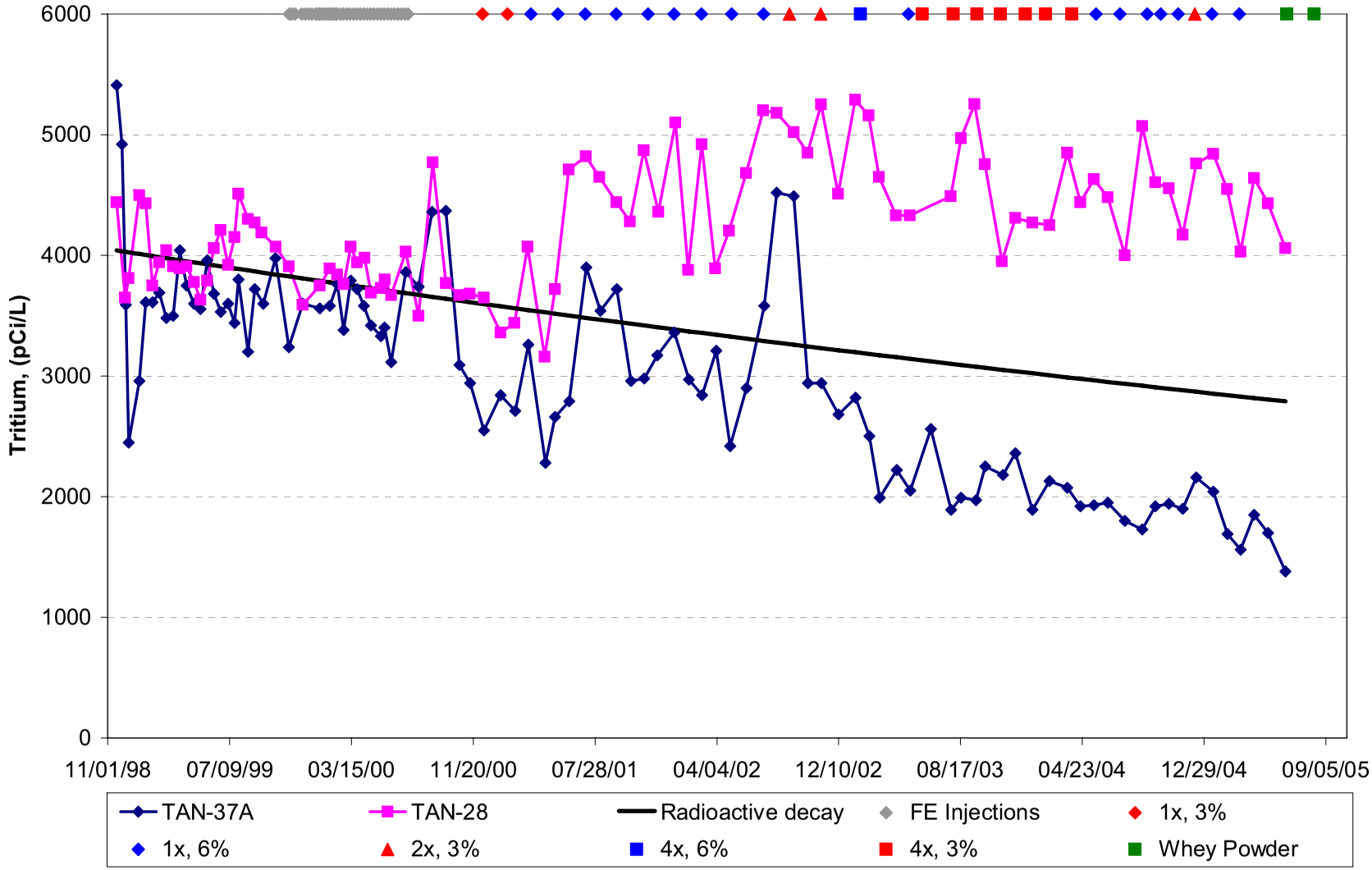

Figure 4-2. Tritium concentration trends in TAN-28 and TAN-37A.

TCE concentrations to TAN-28. Therefore, ISB operations have resulted in an increased dissolution of contaminants from the residual source to the aqueous phase, resulting in increased flux outside the biologically active zone. The fact that both TCE and tritium increase suggests that there is a mechanism, other than what has been demonstrated using high-concentration electron donors, responsible for moving both contaminants from residual source material. This mechanism appears to be a function of the volume of injections, as the increased trends in contaminant concentrations were not observed during the field evaluation when high concentration, small volume injections were performed; however, the trends were observed in subsequent phases when higher volume, lower concentration injections were performed. One plausible explanation is the generation of a pressure pulse created during an injection caused by pressure mounding. Additional data is needed in order to determine if this is a plausible explanation.

The decreasing trend in tritium and TCE measured at TAN-37A suggests just the opposite of what is happening at TAN-28. First, TCE reduction indicates that electron donor has been distributed to a greater extent along the flow path within the source and that the enhanced dissolution properties of the electron donor solutions have either effectively "reduced" the strength of the source or established a reactive zone capable of degradation of TCE more rapidly than it is produced. Second, that source strength reduction can be confirmed with the parallel concentration reduction seen in the tritium data. Tritium will not be affected by enhanced dissolution properties of electron donors, so it can only be reduced by source depletion or a fractionation mechanism related to growth of biomass.

4.1.3 Microbial Community Response to Historical Injections

Data collected following weekly injections of sodium lactate (Phase 1) has provided indirect evidence of a contaminant-degrading microbial community, as determined by declining contaminant concentrations and production of ethene. Data collected during Phases 2 through 4 also provided indirect evidence that the microbial community had been maintained, even as injection strategies have changed. Thus, an active microbial community has been established in the source area wells (TSF-05A, TSF-05B, TAN-25, TAN-31, and TAN-1859), as evidenced by reduction in TCE concentrations as well as accumulation of ethene following injections. In addition, microbial characterization work (i.e., quantitative polymerase chain reaction or terminal restriction fragment length polymorphism) has been performed to provide direct evidence of a significantly active community at TAN-25 in response to electron donor injections.

All of the injection strategies incorporate aerobic potable water as a means to distribute the electron donor. However, following the 4X injections (Phase 3), decreased microbial activity and overall response of the community (lag time initiating ARD of the contaminant) is seen due to the injection of aerobic water over much longer periods of time. The response to decreased microbial activity due to injections of high volumes of aerobic water was less effective ARD and a transient accumulation of cis-DCE.

4.2 Status of Source Remediation

As stated in Section 4.1 and the ISB Remedial Action Work Plan (DOE-ID 2004a), the compliance objectives for the Initial and Optimization Operations phases are to cut off VOC flux in the downgradient (TAN-28 and TAN-30A) and crossgradient (TAN-1860 and TAN-1861) directions and maintain VOC concentrations below the MCLs for a period of 1 year. Various injection strategies have been implemented to identify the most effective strategy to meet this objective. The ISB monitoring program has provided a set of data that can be used to evaluate effectiveness of operations. The ISB annual reports (INEEL 2002a; INEEL 2003a; Armstrong et al. 2004; and Macbeth et al. 2005) present comprehensive VOC data, a complete review of redox data, and evaluation and assessment of microbial community response to various injection strategies. The evaluation of operations performance presented

in this section intentionally focuses on a limited set of data to highlight progress toward attainment of the objective in all monitoring wells located outside the residual source area.

Figure 4-3 is a summary plot of the overall effect of past injection strategies on monitoring locations completed in the upper part of the aquifer. TCE concentration time plots for all of the monitoring wells located outside or external to the residual source area are shown geographically in relation to the source area. The data plotted for TAN-D2, TAN-10A, TAN-27, TAN-37A, and TAN-28 represent variations in TCE concentrations in the upper aquifer (i.e., sampling locations above 280 ft bgs). Sections 4.2.1 through 4.2.4 summarize past injection strategy performance relative to the objective of cutting off flux. Section 4.2.5 addresses monitoring results in the deeper aquifer.

4.2.1 Maintenance of the Bioreactive Zone

As a result of past injections into TSF-05, a biologically active zone, including the ISB wells TSF-05A, TSF-05B, TAN-25, TAN-31, and TAN-1859, has been established. Since microbial populations within this area have been stimulated, microbial biomass has increased. More importantly, specific TCE-degrading microbial populations (e.g., *Dehalococcoides* spp.) have been stimulated and increased in biomass, as evidenced through microbial characterization analysis at TAN-25 (Macbeth et al. 2005). Enhanced populations result in increased degradation rates of contaminants in addition to increased potential for degradation of contaminants (i.e., more microbes can degrade more contaminant). These populations are a result of past injections into TSF-05; accordingly, strategies that include injections into alternate well locations (i.e., TAN-31 or TAN-1859) should consider the time needed to establish populations capable of degrading the contaminant. Microbial populations at TAN-31 and TAN-1859 are included in the biologically active area as indicated by utilization of electron donor distributed to these locations, production of VFAs, and contaminant degradation. However, the extent of healthy, active microbial communities beyond these wells is unknown.

4.2.2 Upper Aquifer Source Remediation – TAN-D2 and TAN-10A

Wells TAN-D2 and TAN-10A represent monitoring locations crossgradient and slightly upgradient of the residual source. Disposal practices at TSF-05 resulted in elevated TCE concentrations at both of these wells. The TCE concentrations at TAN-10A rapidly declined following initiation of ISB operations in 1999. Concentrations steadily declined through 2000 and 2001 and by 2002 had fallen to MCLs or lower. Well TAN-D2 showed a similar pattern, although concentrations were slightly higher—falling from approximately 75 μg/L in 1999 to MCLs or lower by 2003. The concentration of TCE in both wells has remained at or below MCLs for more than 2 years (Figure 4-3).

Performance data from TAN-D2 and TAN-10A indicate that electron donor delivery has encompassed the majority of residual source along flow paths to these two wells. TAN-D2 is closer to the source (approximately 120 ft from TSF-05) and, as would be expected, had higher concentrations for a slightly longer period of time. TAN-10A is further away (approximately 160 ft from TSF-05) and rapidly declining trends in TCE were observed in this well within a year after initiation of amendment injections. Both of these wells continue to show positive results for redox parameters, indicating that there are active flow paths from the source but that TCE migration has been halted due to reaction rates that exceed the dissolution rate or that the source strength along these flow paths has been reduced. These results are a clear indication that ISB operations are effective at cutting off flux from the source area.

4.2.3 Upper Aquifer Source Remediation – TAN-27, TAN-1860, and TAN-1861

Well TAN-27 is located downgradient and crossgradient from the source area (approximately 300 ft from TSF-05). TCE concentrations at this well were initially above 100 μg/L, but, over the first year of ISB operations, concentrations declined to roughly 40 μg/L and very briefly dropped to MCLs.

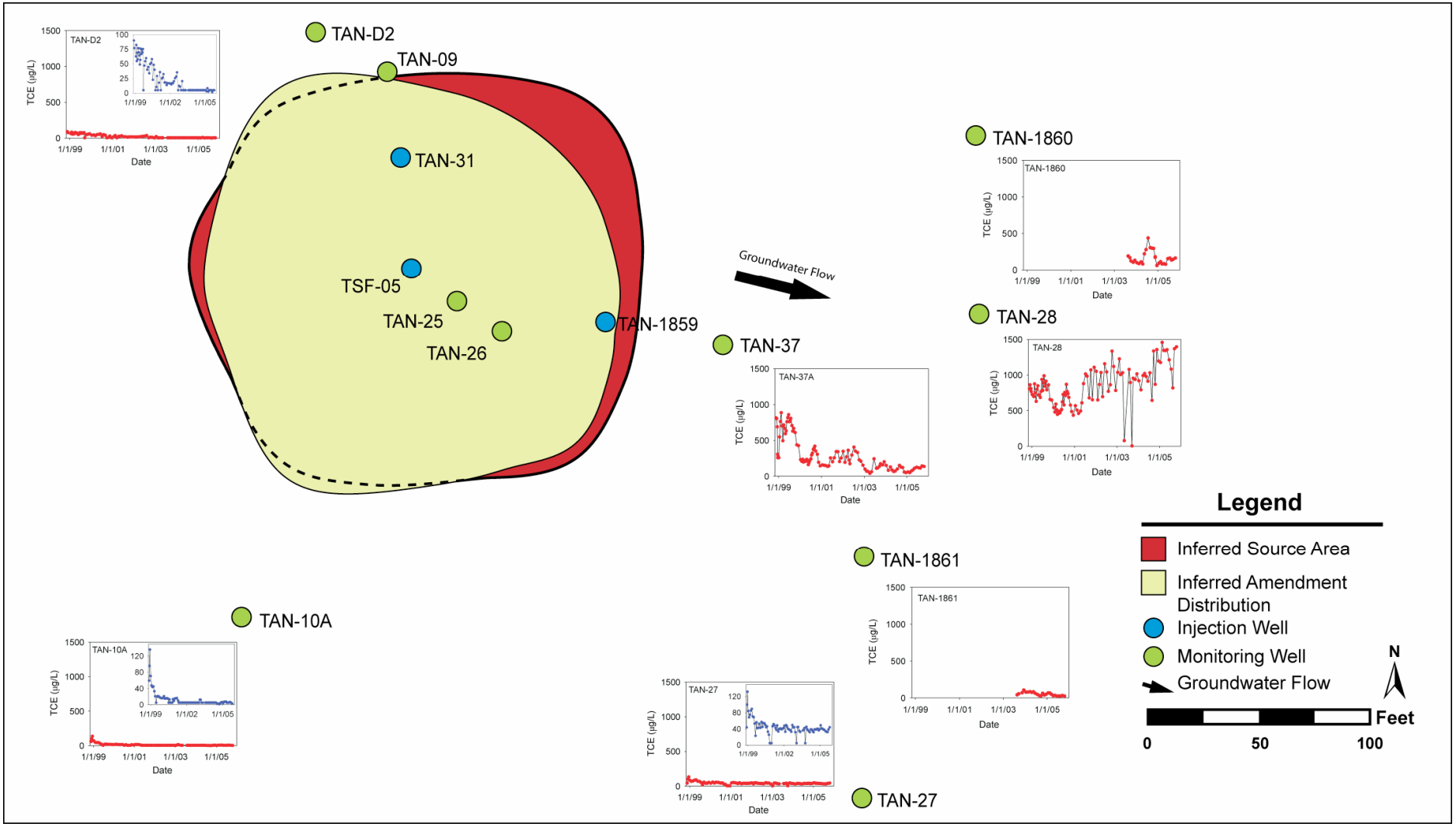

Figure 4-3. In situ bioremediation performance, upper aquifer, 1999–2005. Upper aquifer monitoring wells (sampling locations above 280 ft bgs) include TAN-D2, TAN-10A, TAN-37A, TAN-1860, TAN-28, TAN-1861, and TAN-27.

At the time, this drop was attributed to operation of the Air Stripper Treatment Unit (ASTU). It is believed that the forced gradient created by ASTU operations pulled in flow lines from the source and essentially cut off flow paths from the source to TAN-27. This interpretation is supported by the fact that TCE concentrations rebounded to approximately 40 μg/L soon after ASTU operations terminated. However, TCE concentrations are gradually declining, suggesting that natural gradient flow paths from the source to TAN-27 have not been completely encompassed by electron donor injected at TSF-05.

Wells TAN-1860 and TAN-1861 were drilled from May to September 2003 to provide crossgradient compliance monitoring wells at approximately the same distance from TSF-05 as TAN-28. With only 2 years of monitoring data, it is difficult to identify long-term trends. Currently, the data confirm the representation of the residual source (as shown in Figure 4-3), because TCE concentrations in these wells are significantly lower than concentrations along the axis of the plume. The data for TAN-1860 show a spike in TCE concentration during 2004, at roughly the same time groundwater with the 4X injection fingerprint might be expected to arrive. The uncertainty in travel times makes it difficult to confirm this hypothesis. Additionally, with only 2 years of observation data at this well, it is impossible to determine how the TCE concentrations have fluctuated over time. However, if this is true, it would indicate that there is a flow path in the northeast segment of the source area that has not seen adequate electron donor distribution. Assuming that the TCE spike is related to the 4X injections, this would be consistent with data observed at TAN-28, and also support the argument for a mechanism—other than enhanced dissolution—responsible for moving contaminants out of residual source material.

4.2.4 Upper Aquifer Source Remediation – TAN-37A and TAN-28

Wells TAN-37A and TAN-28 are located along the presumed axis of the TCE plume (146 ft and 260 ft from TSF-05, respectively). TCE and tritium concentrations (shown in Figures 4-1 and 4-2) provide a remarkable example of the effects of bioremediation on the source area. Prior to the start of ISB, the TCE concentrations in both wells were similar. Arrival of the first groundwater impacted by ISB operations shows that the trends in the two wells diverged in opposite directions. Although it might be expected that the well closer to the source (TAN-37A) would exhibit higher concentrations and possibly increasing short-term trends, the opposite is true. The downgradient well (TAN-28) has relatively higher TCE concentrations and the trend over time has increased from approximately 800 μg/L to approximately 1,300 μg/L. The most reasonable explanation for this behavior is the small-scale heterogeneity of the fractured basalt aquifer. The flow paths connecting each of the wells intersect different zones. The flow path to TAN-37A apparently passes through a zone where electron donor distribution has covered more residual source material, whereas the flow path to TAN-28 apparently passes through a zone with less effective coverage of the residual source with electron donor. These results demonstrate that ISB operations can be effective in reducing flux from the source and the importance of distributing electron donor over the entire residual source.

The TAN-37A and TAN-28 data provide a strong case indicating that injection into a single well (e.g., TSF-05) will not distribute electron donor over the entire residual source without substantially increasing the injection volume, which has detrimental effects near the injection location (Armstrong et al. 2004). To meet the objectives set out in the ISB Remedial Action Work Plan (DOE-ID 2004a), the existing injection strategy must be modified. Ideally, this injection strategy would deliver electron donor to the entire residual source area using multiple injection wells, prevent migration of TCE ahead of the electron donor, maintain an acceptable pH in the biologically active area, and meet the objectives to cut off flux downgradient and crossgradient in a timely fashion.

4.2.5 Deep Aquifer Remediation

The discussion above (Sections 4.2.1 through 4.2.4) is focused on the upper part of the aquifer (i.e., sampling locations above 280 ft bgs) where the majority of contamination exists and where the majority of monitoring wells are completed. There are four monitoring wells completed in the deep aquifer (i.e., sampling locations deeper than 280 ft bgs): TAN-09, TAN-26, TAN-37C, and TAN-30A. Figure 4-4 presents TCE concentration time plots for the four wells. TAN-09 was included in the monthly monitoring program starting in April 2005. Data collected in 2005 roughly correspond to the one data point from 1999; however, more data will be required to establish a representative trend.

From a performance perspective, TAN-26, TAN-37C, and TAN-30A demonstrate that ISB was effective in creating enhanced dissolution (the spike in TCE concentration in all three wells) and in creating a reactive zone supporting degradation of the increased TCE. In TAN-26, TCE concentrations have declined to MCLs or below and have remained there for the past 5 years. TAN-37C was initially low, saw a spike in TCE in October 1999, and then returned to low concentrations. The furthest downgradient well, TAN-30A, also saw an increase in TCE concentrations followed by a decrease that is trending toward MCLs. Taken together, these wells provide evidence that single well injections in TSF-05 have been effective but that increasing electron donor distribution will further improve the performance of the ISB source area remedy.

4.3 Injection Strategy Optimization for Enhanced Electron Donor Distribution

As stated in Sections 4-1 and 4-2, the ISB remedy has effectively operated by stimulating ARD in the portions of the source area directly impacted by electron donor injections. However, current injection strategies are not (1) meeting the ISB Initial Operations objective of cutting off downgradient flux to TAN-28 or (2) working toward meeting the goal of ISB Optimization Operations (i.e., cutting off crossgradient flux to TAN-1860 and TAN-1861). In order to meet these objectives, electron donor must be distributed throughout the entire residual source area. This section presents a plan for optimizing the injection strategy in order to enhance electron donor distribution. The objectives for enhancing electron donor distribution include the following:

- Cutting off flux of VOCs to TAN-28:
    - Establish a declining TCE trend at TAN-28
    - Decrease TCE concentrations at TAN-28 to below MCLs
- Creating a biologically active zone around TSF-05 that encompasses the entire residual source area:
    - Target electron donor distribution to reach the downgradient and crossgradient edges of the residual source material
    - Monitor injections to determine connectivity between ISB wells and distribution of electron donor
    - Maintain acceptable pH in the biologically active zone
- Enhancing the dissolution of TCE in the biologically active zone.

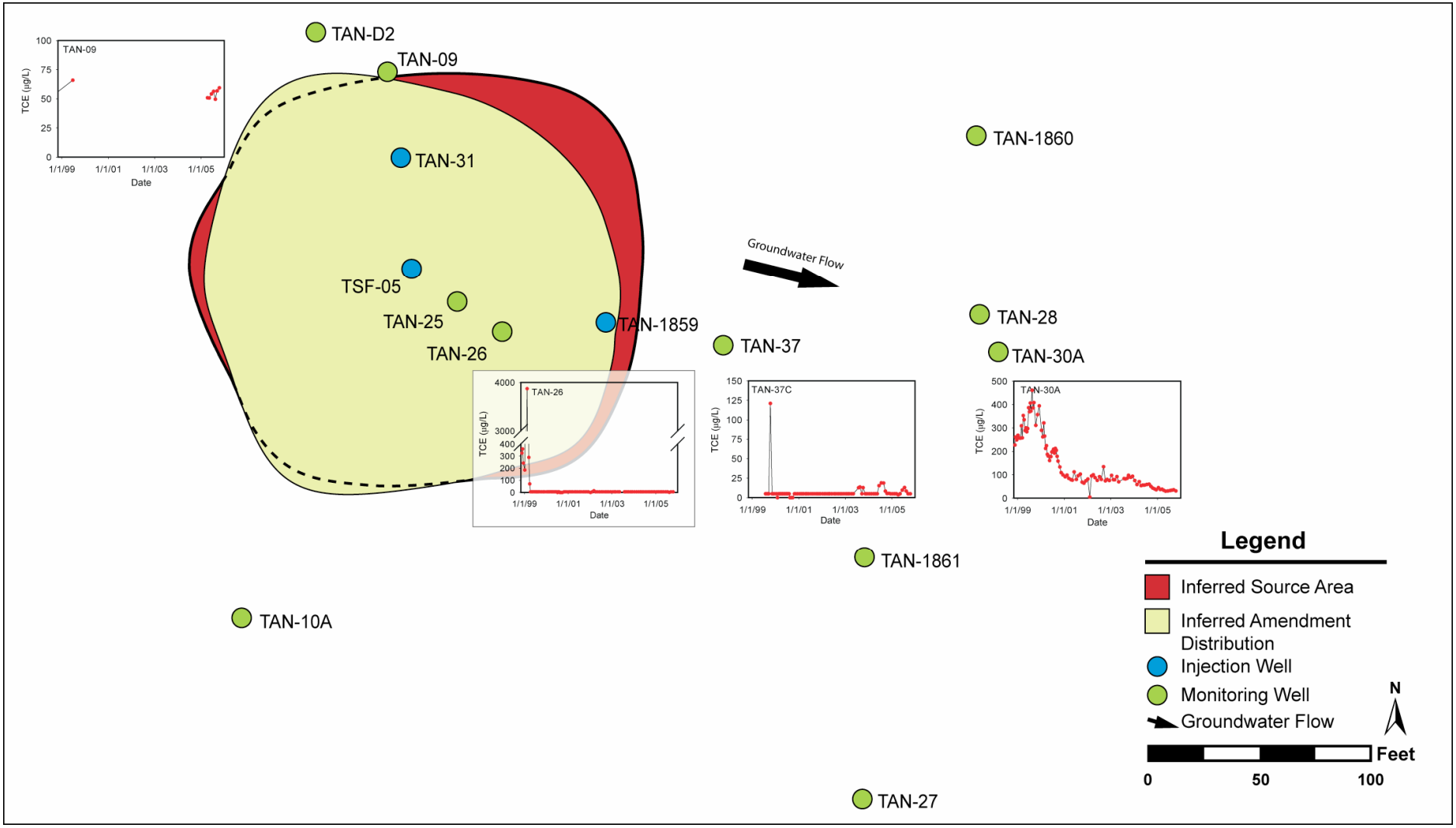

Figure 4-4. In situ bioremediation performance, deep aquifer, 1999–2005. Deep aquifer monitoring wells (sampling locations deeper than 280 ft bgs) include TAN-09, TAN-26, TAN-37C, and TAN-30A.

The present ISB injection system has the capability to inject into three different wells (TSF-05, TAN-31, and TAN-1859). As part of construction activities implemented under the ISB Remedial Action Work Plan (DOE-ID 2004a), TAN-31 and TAN-1859 were modified so that electron donor injections can be performed into these two wells. As stated in the ISB Remedial Action Work Plan, "multiple injection locations are required to obtain effective amendment distribution." Residual source material, as evidenced by gamma logs (Figure 4-5), is present in the vicinity of both TAN-31 and TAN-1859. Additionally, increased COD concentrations are detected at both wells following injections into TSF-05, indicating that these wells communicate with TSF-05. The possible alternative types of injections to encompass the residual source area include the following:

- **Single well injections—**

  - **TSF-05**. Past injections into TSF-05 have distributed electron donor to residual source material in and around this well; however, the injections have not encompassed the entire residual source area, as evidenced by increasing TCE concentrations in TAN-28, TAN-1860, and TAN-1861.

  - **TAN-31**. Although TAN-31 has been modified as an injection well, an electron donor injection has never been performed into this well. Injections into TAN-31 will enhance the TCE degrading community in this area, which is known to contain residual source material. Creating a larger TCE degrading community in the vicinity of TAN-31 could result in cutting off crossgradient flux to TAN-1860. Initial injections into TAN-31 will be closely monitored to determine if electron donor is adequately distributed, pH is maintained at an acceptable level, and the microbial community is responding appropriately.

  - **TAN-1859**. Previous electron donor injections into TAN-1859 (December 2003 and February 2004) were not successful, as there was significant vertical transport of lactate resulting in negligible distribution of electron donor outside of TAN-1859 (ICP 2004). Therefore, before future injections are attempted in this well, a packer will be installed to direct distribution of electron donor to the upper part of the aquifer. Since TAN-1859 is located near the downgradient edge of the residual source area, the goal of injections at this location is to distribute electron donor and establish an area of reductive dechlorination at the edge of the residual source in order to reduce TCE flux in both the downgradient and crossgradient directions. Initial injections into TAN-1859 will be closely monitored to determine if electron donor is adequately distributed, pH is maintained at an acceptable level, and the microbial community is responding appropriately.

- **Simultaneous injections into two wells (TSF-05 and TAN-31; TSF-05 and TAN-1859; or TAN-31 and TAN-1859)—**With minor modifications to the injection system, a simultaneous and continuous injection can be performed into two wells. The advantages of simultaneous injections include: (1) from a hydrological standpoint, the injections will be "pushing" against one another to drive electron donor to areas potentially not reached by injections into one well alone; (2) a larger mass of electron donor will be delivered to the subsurface at one time; and (3) optimization of the injection strategy into multiple wells will "capture" TCE that has previously been pushed from the source area without associated electron donor. This TCE that was previously driven from the source area due to past injection strategies has theoretically been the source of increasing TCE concentrations in TAN-28.

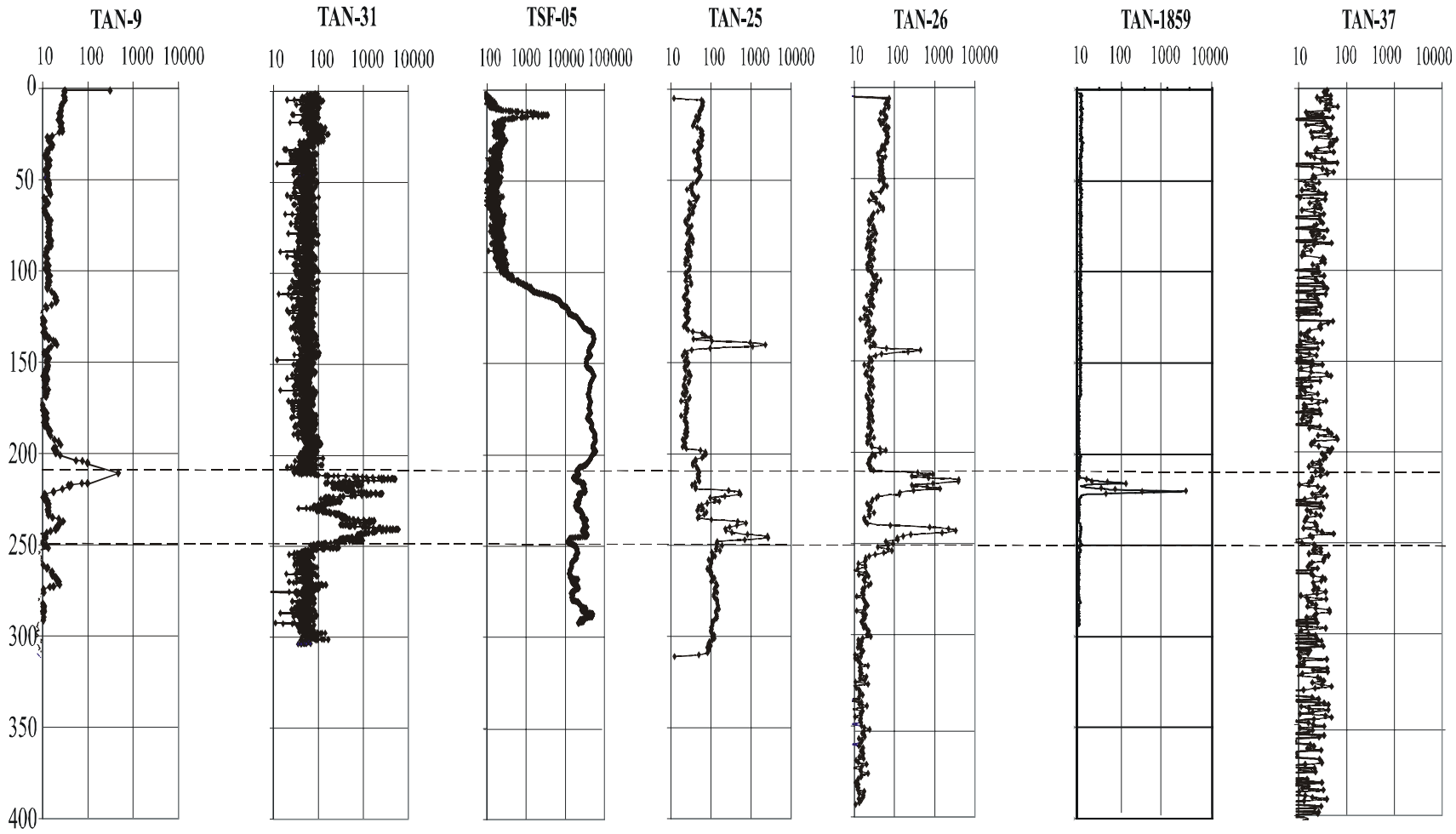

Figure 4-5. Correlation of gamma readings and depth of screened intervals (listed in parentheses) for the wells: TAN-9 (300–322 ft bgs), TAN-31 (open borehole), TSF-05 (180–244 and 269-305 ft bgs), TAN-25 (217–297 ft bgs), TAN-26 (368–408 ft bgs), TAN-1859 (open borehole), and TAN-37 (open borehole).

- **Simultaneous injections into three wells (TSF-05, TAN-31, and TAN-1859)—**Performing simultaneous injections into three wells would yield similar predicted results as the simultaneous injections into two wells except on a larger scale. However, injecting into three wells at once would require significant modifications to the injection system or the use of a portable injection system in addition to the present injection system. Also, an additional source of potable water (i.e., frac tank filled with potable water) would need to be available for the injection.

Based on these alternatives and the current configuration of the ISB injection system, the best way to increase the effective distribution of electron donor over the entire residual source area will include a combination of single well injections and simultaneous injections into two wells. Implementation of the proposed injection strategy will be accomplished in three steps, as follows:

1. **Enhance the biologically active zone around TAN-31 and TAN-1859—**This will be accomplished by performing injections into each well individually. The objectives using TAN-31 and TAN-1859 to enhance the biologically active zone will be to: (1) distribute electron donor beyond the area of influence of the TSF-05 injections, (2) develop a larger biologically active zone to encompass the entire residual source area, (3) degrade the source material within the residual source area, and (4) cut off flux to downgradient locations.

   Both TAN-1859 and TAN-31 contain residual source material, as evidenced by gamma logs of the wells (Figure 4-5), and both wells are influenced by injections into TSF-05, as evidenced by electron donor distribution to these wells (Attachment A; Macbeth et al. 2005). However, only low concentrations of electron donor have been distributed to TAN-1859, so negligible enhanced dissolution effects have been observed. The delivery of high concentrations of electron donor solution will likely increase the total mass and rate of dissolution and subsequent degradation of contaminants in and around these locations. In addition, distribution of electron donor will occur to a farther extent down and upgradient of both TAN-1859 and TAN-31 likely impacting areas not currently impacted by injection into TSF-05 alone. The expansion of the area containing an active TCE degrading community will allow degradation of TCE released from the source area currently unimpacted by TSF-05 injections.
2. **Maintain the biologically active zone around TSF-05—**Injections will be performed using TSF-05, either as a single well injection or during a two-well simultaneous injection, to maintain the existing biologically active zone around TSF-05.
3. **Enhance electron donor distribution using two-well simultaneous injections—**The objective of using two-well simultaneous injections is to distribute electron donor to a large portion of the downgradient and crossgradient locations of the residual source area. The advantages of the two-well simultaneous injections include electron donor distribution and TCE dissolution over a greater area of the residual source than just using a single well injection.

Based on historical injection strategy results, it is best to implement one type of injection strategy for several months (i.e., at least 12 months) at a time to accurately observe the effects of the injections. The injection strategy will be monitored for effectiveness throughout implementation. Parameters for evaluation of the effectiveness of the injection strategy will include:

- Locations of electron donor distribution
- Timeframe of pH rebound
- Production of ethene
- Rebound in sulfate or TCE concentrations
- Presence and activity of microbial populations.

5. CONCLUSIONS

The goals of the current operational phase of the ISB component of the OU 1-07B remedy are to cut off downgradient (TAN-28 and TAN-30A) and crossgradient (TAN-1860 and TAN-1861) VOC flux and maintain VOC concentrations below the MCLs for a period of 1 year. Activities conducted during this reporting timeframe demonstrate progress toward these goals. The timeframe of this ISB annual report coincides with the second year of activities conducted as part of the Initial Operations Phase. This reporting period includes (1) completion of the AED optimization in June 2005 to evaluate the effectiveness of whey powder in comparison to sodium lactate, and (2) routine injections and subsequent groundwater monitoring from July 2005 through September 2005.

The AED optimization (Attachment A) allowed for an in-depth evaluation of the geochemical, microbial, and contaminant response to injections of sodium lactate and whey powder. The distribution of each of the amendments was similar, although higher concentrations of whey were observed at all of the effected monitoring locations due to the higher concentration solution injected (10% w/w vs. 6%). One advantage of whey is the ability to effectively distribute high concentrations of amendment without the density-driven effects observed with high concentrations of sodium lactate (DOE-ID 2000).

The ability to deliver more amendment throughout the biological treatment area had key implications as to the effect on geochemistry and contaminant concentrations. First, whey powder is comprised of 70–75% lactose (a sugar), which rapidly ferments at approximately 2-–3 times higher rate than lactate, and subsequently produces high concentrations of acid rapidly. For example, the 18,000–24,000 mg/L of lactose that is injected in and around TSF-05 was depleted within the first week of injection, compared to the 10,000–15,000 mg/L of lactate depleted within 2 weeks of injection, and with each mole of lactose degraded, approximately 2-4 moles of acid are produced. During lactose fermentation, the pH dropped at the impacted wells (TSF-05A, -05B, TAN-25, and TAN-31) from approximately 7.0–7.2 to approximately 5.0–5.3 compared to the drop to 6.2–6.5 following lactate fermentation. At TAN, high alkalinity and biological activity that were present as a result of 5 years of lactate injections, however, provide a high buffering capacity in and around TSF-05 so that the pH recovered within a reasonable timeframe (2–3 weeks) following the whey injections.

Most microbes, including *Dehalococcoides* spp. (the organism identified at TAN capable of degrading TCE to ethene), have the highest activity rates near neutral pH. In particular, the activity of several dehalogenase enzymes from different *Dehalococcoides* spp. were substantially reduced (by approximately 25–75%) near pH <6, and inactive near pH <5.5. The degradation of cis-DCE and VC in particular is inhibited by low pH. This is somewhat reflected at TAN, where following each injection the solubilized TCE was degraded to cis-DCE during the first week, but substantial ethene production was not observed until after the pH had recovered to above 5.5. Delayed ethene production also was observed, however, following each sodium lactate injection, suggesting that this phenomenon is caused by factors other than pH. In particular, the lag period before the observed stoichoimetric production of ethene was virtually identical during the sodium lactate and whey powder injection cycles.

The molecular microbial data collected from TAN-25 suggest that there is a drop in *Dehalococcoides* spp. evident around the Day 22-23 sampling following the whey powder injection. Although the pH had recovered at most locations by this point, there is a lag during the time when a cell dies and when the DNA is degraded in a sample. Therefore, the response of this species to the pH drop may have been time shifted using quantitative polymerase chain reaction on DNA. This group rapidly recovers, however, by the Day 35-36 sampling, which is reflected in the high production of ethene that is observed in conjunction to the observed growth. Collectively, these data suggest that although there may be a temporary reduction in growth and activity of contaminant-degrading microbes during the period of

low pH, the microbial community recovers, and operationally the system performs very similarly in terms of ethene production to sodium lactate.

One advantage of the drop in pH, however, was the lower utilization of electron donors, especially the secondary fermentation products butyrate, propionate, and acetate following whey powder injection. The utilization rate coefficient for COD was evaluated using field data collected following the sodium lactate and whey powder injections. The utilization rate of whey powder was nearly the same as observed for sodium lactate. This was somewhat surprising given that laboratory microcosm studies using a culture derived from TAN-25 suggested that the utilization rate for whey was twice as high as for sodium lactate (Attachment A). In these microcosm studies, however, the concentration of whey used was much lower and a drop in pH was not observed. The lower utilization rate in the field suggests that whey powder has a much higher longevity than predicted, which ultimately resulted in the ability to inject less frequently and still maintain efficient reductive dechlorination. In fact, electron donor injections were discontinued for over 7 months following the three AED optimization injections, and high concentrations of ethene were maintained within the biologically active area over this entire duration. Only a small spike in cis-DCE observed at TSF-05B just prior to the July 2005 whey injection suggested that the biological system was becoming less efficient. The ability to maintain efficient ARD within the treatment system at TAN for at least seven months between injections will provide significant flexibility in designing an optimal injection strategy that will achieve the site remedial objectives.

Strontium-90 (Sr-90) samples collected at TAN-25 on a monthly basis were evaluated to determine any effect of the transition from sodium lactate to whey powder on radionuclide concentrations. The drop in pH observed immediately after both the sodium lactate and the whey powder injections correlated to measureable spikes in Sr-90 at this location. In addition, the spikes were greater following the whey powder injections because of the lower pH. One month after injection, however, concentrations returned to baseline levels. In addition, no increases in Sr-90 were observed at any downgradient location suggesting that the transient pH effect observed at TAN-25 does not result in measurable downgradient migration. In order to ensure that downgradient migration of Sr-90 does not occur, however, more frequent sampling is recommended at the downgradient locations.

The second dramatic effect of injecting high concentrations of whey throughout the residual source area at TAN was the contaminant concentration response. Higher concentrations of TCE were observed throughout the residual source area directly following injection with whey powder as compared to sodium lactate, especially at TSF-05B and TAN-25. In addition, higher total molar concentrations of contaminants were observed during an injection cycle, including higher concentrations of ethane, approximately 1 month after injections. These data collectively suggest that more mass is degraded over a whey powder injection cycle, as compared to a sodium lactate, which will result in a shorter remedial timeframe, and reduce flux of contaminants to downgradient locations with continued use of whey powder.

The cessation of flux of contaminants to downgradient locations, specifically to TAN-28, is a major goal of the current operational phase of the remedy at TAN. Six years of single well injections into TSF-05 have not yet achieved the goal of cutting off flux to this location. Data collected at TAN-37B suggest that whey powder injections did result in significant decreases in contaminant flux to this location, as measureable COD, a drop in sulfate, decreased concentrations of TCE to non-detect, and measurable cis-DCE and ethene were observed following the whey powder injections. Data collected from TAN-28, however, suggest that the single well whey powder injections did not affect flux of contaminants to this location. Therefore, in order to meet this remedial objective, a multi-well injection strategy using TAN-1859 and TAN-31 was outlined in Section 4.3. The ability to distribute high concentrations of whey will help in achieving a radial area of influence large enough to cut off flux to TAN-28, and the enhanced dissolution properties will result in greater contaminant mass destruction over time using the multi-well approach.

One effect of whey that must be mitigated in the multi-well design is the pH effect, with the approach for injections into TAN-31 and TAN-1859 designed differently based on past exposure to amendments. High concentrations of both sodium lactate and whey powder have been routinely distributed to TAN-31, resulting in high biomass and alkalinity at this location. Therefore, it is anticipated that 10% w/w whey powder solution injection into this location is currently feasible. TAN-1859, however, has been impacted only minimally by electron donor injections into TSF-05 (~100 mg/L as COD) and therefore has much lower biomass and alkalinity. Therefore, the initial injections into this location should be low-concentration lactate and/or whey until biological activity and alkalinity is sufficiently high to begin the 10% w/w injections.

It is anticipated that at least 1 year of monitoring will be required in order to observe the effects of the multi-well injection strategy at TAN-28. The effects of the multi-well injection will be observed as changes in geochemical and/or contaminant responses at TAN-37 and TAN-28 in the near term and ultimately at TAN-1860 and TAN-1861 in the long term. Therefore, the timeframe for the optimization of the multi-well injection strategy may extend beyond reporting period 2006.

In general, the ISB remedy continues to operate effectively, stimulating ARD throughout most of the source area. Ethene was present in significant concentrations in all biologically active wells, indicating active ARD. The results of the AED optimization activities completed during this reporting period provided evidence that whey powder is a more efficient and cost-effective electron donor. The goal of the Initial Operations Phase is to eliminate flux of VOCs from the source area to downgradient locations, specifically TAN-28 and TAN-30A. Implementation of the injection strategy to enhance electron donor distribution will work toward achieving the goals of the Initial Operations Phase to effectively distribute electron donor to the entire source area, sustain efficient ARD conditions, and cut off flux of VOCs from the residual source.

6. RECOMMENDATIONS

The following recommendations are based on the results and discussions presented in this report:

- Based on results of the AED optimization, use whey powder for future ISB injections
- Implement an injection strategy that will achieve remedial goals and distribute electron donor across the entire residual source area using a multi-well injection approach (as described in Section 4.3)
- As a best management practice, conduct monthly monitoring for Sr-90 at TAN-37A and TAN-37B, and quarterly monitoring at TAN-28 and TAN-29.
- Implement the modifications to the ISB monitoring program during FY 2006, as directed by Revision 3 of the ISB Groundwater Monitoring Plan (ICP 2005), which includes the following changes:
  - Reduce sampling frequency for TAN-10A, TAN-26, TAN-27, TAN-37C, and TAN-D2 to quarterly monitoring
  - Add quarterly monitoring of TAN-09
  - Discontinue semiannual sampling for nutrients (ammonia-nitrogen and phosphate).

Table 6-1 presents a summary of the performance monitoring strategy to be implemented during Fiscal Year 2006.

Table 6-1. Summary of in situ bioremediation performance monitoring for Fiscal Year 2006.

Monitoring Frequency	Monthly (twelve times per fiscal year)	Quarterly (four times per fiscal year)	Semi-annually (two times per fiscal year)
Monitoring Locations	TSF-05A, TSF-05B, TAN-25, TAN-28, TAN-29, TAN-30A, TAN-31, TAN-37A, TAN-37B, TAN-1859, TAN-1860, and TAN-1861	TAN-10A, TAN-26, TAN-27, TAN-37C, TAN-D2, and TAN-9	All wells
Analytes	• VOCs (PCE, TCE, cis-DCE, trans-DCE, and VC) • Electron donors (COD, lactate or lactose, acetate, propionate, butyrate, isobutyrate, isovalerate, valerate, hexanoate, and formate) • Redox parameters (ferrous iron, sulfate) • Bioactivity parameter (alkalinity) • Dissolved gases (ethene, ethane, methane) • Tritium	• VOCs (PCE, TCE, cis-DCE, trans-DCE, and VC) • Electron donors (COD, lactate or lactose, acetate, propionate butyrate, isobutyrate, isovalerate, valerate, hexanoate, and formate) • Redox parameters (ferrous iron, sulfate) • Bioactivity parameter (alkalinity) • Dissolved gases (ethene, ethane, methane) • Tritium	Definitive confirmation (off-Site splits) for VOCs

COD = chemical oxygen demand
DCE = dichloroethene
PCE = tetrachloroethene
TCE = trichloroethene
VC = vinyl chloride
VOC = volatile organic compound

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Attachment A

Details of the Alternate Electron Donor Optimization

CONTENTS

FIGURES

TABLES

Attachment A

Details of the Alternate Electron Donor Optimization

A-1. INTRODUCTION

In situ bioremediation (ISB) is the remedy selected for restoration of the hot spot of the groundwater plume at Test Area North (TAN) Operable Unit (OU) 1-07B of the Idaho National Laboratory (INL) Site. Current ISB operations are governed by the *In Situ Bioremediation Remedial Action Work Plan for Test Area North Final Groundwater Remediation, Operable Unit 1-07B* (DOE-ID 2004a). The ISB remedy consists of regular injections of sodium lactate to stimulate bioremediation of chlorinated hydrocarbons in the contaminant source area of the groundwater plume. Part of the scope of operations under the ISB Remedial Action Work Plan is to evaluate an alternative electron donor (AED) to sodium lactate. Activities have been performed to evaluate various AEDs in laboratory studies and in the field.

A summary of the details presented in this attachment is included in Section 2 of the main text of this Fiscal Year 2005 ISB Annual Report. This attachment is organized to present the objectives of the AED optimization (Section A-2), the implementation strategy (Section A-3), the results (Section A-4) and a detailed analysis of the data (Section A-5) to draw conclusions (Section A-6) and make recommendations (Section A-7) for future ISB operations. In addition, three appendices are included at the end of this attachment to provide additional supporting information. Appendix A includes SAP tables for the AED optimization, Appendix B details the AED optimization sampling schedule, and Appendix C provides quality assurance details for the AED optimization.

A-2. OBJECTIVE OF THE ALTERNATE ELECTRON DONOR OPTIMIZATION

Several AEDs (Table A-1) were evaluated in laboratory tests including interfacial tension measurements and column studies to evaluate enhanced dissolution properties, TAL metals to ensure the substrate could be injected into the aquifer without posing health risks, dechlorination to ensure the substrate stimulated anaerobic reductive dechlorination, and molecular characterization to determine if the substrate stimulated a microbiological community that supported ARD and to determine if any negative effects could be observed. The ultimate goal of the laboratory tests was to collect evidence to decide if one of the AEDs evaluated was potentially more effective than sodium lactate for use during ISB operations at TAN. As a result of the laboratory tests, which were designed to directly compare the AEDs relative to sodium lactate, whey powder was selected as the electron donor for evaluation for long-term use at TAN. Laboratory evidence suggested that whey powder: (a) enhanced the dissolution of TCE DNAPL in batch and column studies to a greater extent than sodium lactate, (b) had comparable dechlorination efficiency when compared to sodium lactate, and (c) was less expensive than sodium lactate or other AEDs.

Based on the results of the laboratory work, a field scale evaluation using whey powder was conducted in the TAN OU-107B residual source area. The objective of the AED optimization is to determine whether or not the use of whey powder for long-term full-scale operations will improve system performance and decrease the cost of in situ bioremediation (ISB) at Test Area North (TAN) at the Idaho National Laboratory (INL) Site.

Table A-1. Summary of alternate electron donors evaluated through laboratory studies as a component of Interim Operations.

Electron donor	Interfacial Tension	TAL Metals	Dechlorination	Molecular Characterization	Column Test
Sodium Lactate[a, b]	X	X	X	X	X
Feed-grade molasses[a]	X	X	X	X	
Food-grade molasses[a]	X	X	X	X	
Liquid whey[a]	X	X	X	X	
Whey powder[b]	X	X	X	X	X
Ethyl lactate/sodium lactate[a]	X	X			
Ethyl lactate/sodium dipropionate[b]	X	X	X	X	X
Sodium dipropionate[a,b]	X	X	X	X	X
Sodium propionate[b]	X	X	X	X	
Ground lactose[a]	X				
Unground lactose[a]	X				
LactOil™ [a,b]	X	X	X	X	
LactOil™/sodium propionate[b]	X		X	X	
Purified Dairy Carbohydrate[a]	X				
Unpurified Dairy Carbohydrate[a]	X				

a. Indicates laboratory studies reported in FY 2003 ISB Annual Report (Armstrong et al. 2004).
b. Indicates laboratory studies conducted in FY 2003.

The AED field optimization was conducted from March 2004 through June 2005 to evaluate whey powder relative to sodium lactate during ISB operations within the TAN residual source area. The *Alternate Electron Donor Optimization Plan for ISB Operations at Test Area North Operable Unit 1-07B* (Harris and Hall 2004) defined the approach and requirements for evaluating whey powder as an alternative donor to sodium lactate. Objectives included comparing the results of sodium lactate and whey powder injections using the following criteria:

- Electron donor distribution
- Electron donor utilization
- Geochemistry parameters
- TCE concentration trends
- Anaerobic reductive dechlorination (ARD)

- Microbial community health
- Radionuclide concentrations
- Cost.

A-3. IMPLEMENTATION OF THE AED OPTIMIZATION PLAN

The AED optimization consisted of two baseline 1X 6% nominal concentration sodium lactate injections (Section A-3.1) and three 1X 10% w/w whey powder injections (Section A-3.2). High-frequency groundwater monitoring was conducted within the biologically active area at TAN following each injection (Section A-3.3).

A-3.1 Baseline Sodium Lactate Injections

Table A-2 presents the details of the two baseline sodium lactate injections. Sodium lactate was purchased as 60% solution by weight (w/w). The "Injection Type" column refers to the approximate volume of sodium lactate plus potable water injected, as well as the intended nominal sodium lactate concentration. The actual concentrations, calculated based on the "Total Volume of Sodium Lactate Solution Injected," are presented in the "Resultant Sodium Lactate Concentration" column. Two injections of approximately 12,000 gal of 6% concentration (noted as 1X 6% in Table A-2 and other figures in this report) sodium lactate were performed as the sodium lactate baseline for comparison to whey powder injections (Section A-3.2) during the AED optimization.

Table A-2. Baseline sodium lactate injections during the alternate electron donor optimization.

Injection Date	Volume 60% (w/w) Sodium Lactate Injected (gal)	Injection Type	Total Volume of Sodium Lactate Solution Injected (gal)	Resultant Sodium Lactate Concentration (%)	Combined Injection Flow Rate[a] (gpm)	Potable Water Flush Volume (gal)
March 15, 2004 (TSF-05)	1,355	1X 6%[b]	12,950	5.7	41.0	2,250
May 10, 2004 (TSF-05)	1,355	1X 6%	14,162	5.2	40.0	2,202

a. The combined injection flow rate represents the addition of the lactate injection flow rate and the potable water flow rate during the timeframe of the injection.
b. 1X 6% = an injection volume of approximately 12,000 gal and a 6% concentration of sodium lactate.

A-3.2 Whey Powder Injections

Table A-3 presents the details of the whey powder injections. Whey powder was purchased in 2,000-lb totes of feed grade material consisting of 70 to 75% lactose, 10 to 13% protein, and 7 to 13% ash. The "Injection Type" column refers to the approximate volume of whey powder plus potable water injected, as well as the intended nominal whey powder concentration. The actual concentrations, calculated based on the "Total Volume of Whey Powder Solution Injected," are presented in the "Resultant Whey Concentration" column. Three whey powder injections of approximately 12,000 gal of 10% w/w concentration (1X 10%) whey powder were performed for the AED optimization.

Table A-3. Whey powder injections during the alternate electron donor optimization.

Injection Date	Mass of Whey Powder Injected (lb)	Injection Type	Total Volume of Whey Powder Solution Injected (gal)	Resultant Whey Concentration (%w/w)	Combined Injection Flow Rate (gpm)	Potable Water Flush Volume (gal)
August 16, 2004 (TSF-05)	9,800	1 X 10%[a]	13,157	9.72	36	1,842
October 11, 2004 (TSF-05)	9,730	1 X 10%	13,660	9.28	35	1,824
January 10, 2005 (TSF-05)	10,000	1 X 10%	15,274	8.50	35	1,836

a. 1X 10% = an injection volume of approximately 12,000 gal and a 10% concentration of whey powder.

A-3.3 Groundwater Monitoring

For the AED optimization, the sampling strategy detailed in the AED Optimization Plan (Harris and Hall 2004) was performed in accordance with the *In Situ Bioremediation Remedial Action Groundwater Monitoring Plan for Test Area North, Operable Unit 1-07B* (INEEL 2003a). This strategy implemented high-frequency groundwater monitoring in conjunction with routine monthly ISB monitoring. The high-frequency groundwater monitoring was conducted in a subset of the ISB monitoring wells (Section A-3.3.1). The schedule for routine monthly ISB monitoring and high-frequency monitoring performed during the AED optimization is presented in Section A-3.3.2 and analytical parameters collected are stated in Section A-3.3.3.

A-3.3.1 Monitoring Well Network

Five ISB monitoring locations were included in the high-frequency groundwater monitoring conducted as part of the AED optimization. TSF-05A, TSF-05B, TAN-25, and TAN-31 were included during the entire optimization, while TAN-1859 only was included following the third whey powder injection, January–June 2005. The locations of these wells are shown in Figure A-1. Table A-4 provides details of the depths sampled and the horizontal distance of each sampling point from the TSF-05 injection well.

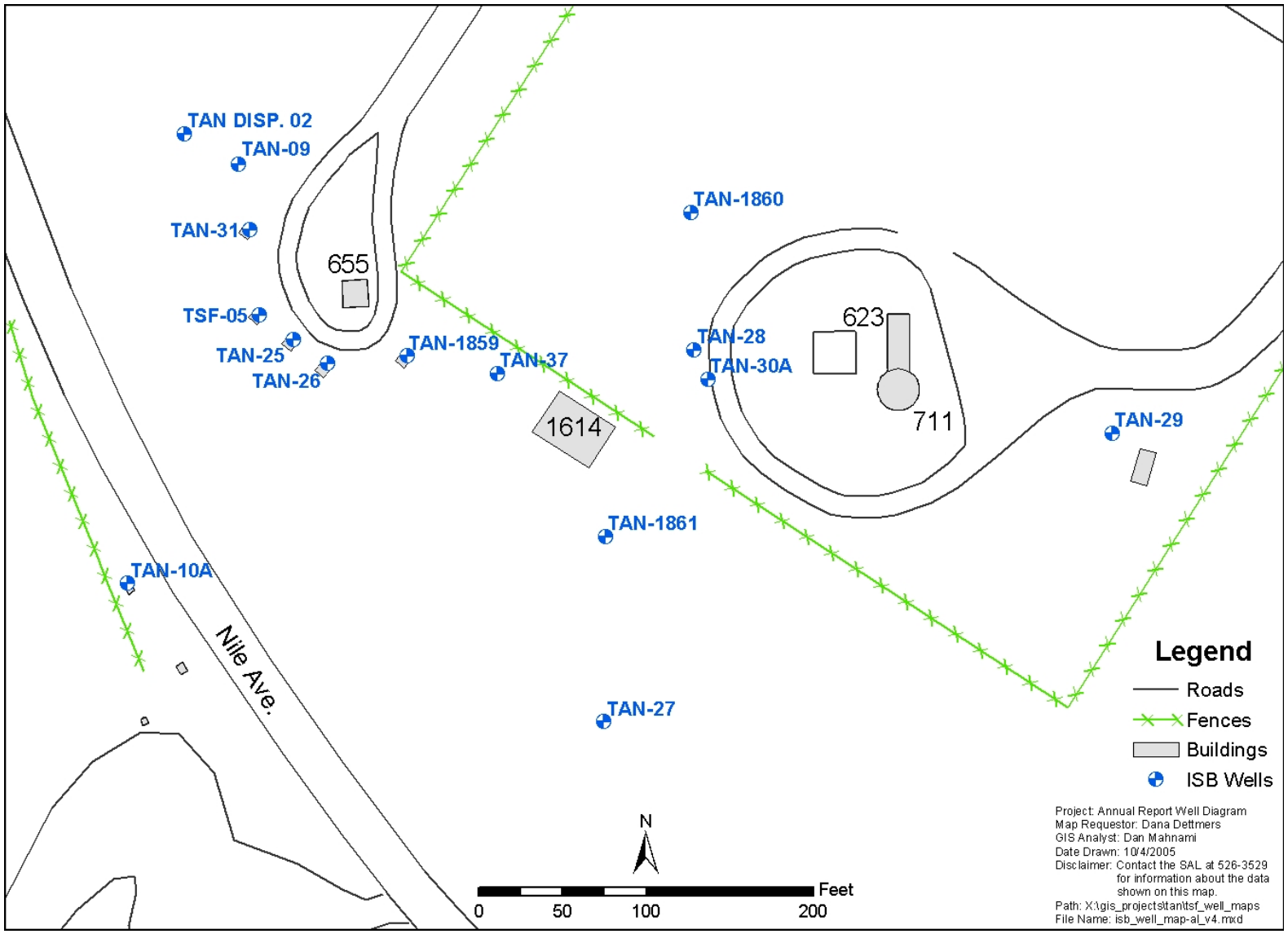

Figure A-1. In situ bioremediation groundwater monitoring locations. High-frequency monitoring locations for the alternate electron donor optimization included TSF-05, TAN-25, TAN-31, and TAN-1859.

Table A-4. Details of the high-frequency groundwater monitoring locations during the AED optimization.

Well	Depth Sampled (ft)	Distance from TSF-05 (ft)
TSF-05A[a]	235	0
TSF-05B[a]	270	0
TAN-25	218	25
TAN-31	258	50
TAN-1859	250	92

a. TSF-05 is sampled at two depths. The letter following the well name is used to represent the sample depth.

A-3.3.2 Sampling Schedule

The Sampling and Analysis Plan (SAP) tables for the AED optimization are included in Appendix A (which is an appendix to this attachment), and the schedule of sampling conducted during the AED optimization is shown in Appendix B of this attachment. Details for each of the sampling events include the sampling date, monitoring location, and analyte set. Data collected during the AED optimization include ISB monthly sampling events in addition to the high-frequency sampling events.

For scheduling and data interpretation purposes, the day of the electron donor injection is identified and labeled as Day 1. In general, sampling conducted during the AED optimization was performed on:

- Day 2,
- Day 4,
- Days 8–10 (these days correspond with monthly ISB sampling),
- Day 15 (sampling was only conducted on Day 15 following the October 11, 2004, and January 10, 2005, whey injections),
- Days 22 or 23,
- Days 36–38 (these days correspond with monthly ISB sampling),
- Days 64–65, or Days 71–73 (these days correspond with monthly ISB sampling).

Following the January 10, 2005, whey injection, sampling was also conducted on Days 78–79, 92–93 (ISB monthly sampling event), 106, 120–121(ISB monthly sampling event), 135, and 156–158 (ISB monthly sampling event). The days after injection and date for all sampling events are shown in Table A-5.

Table A-5. Summary of alternate electron donor optimization sampling events.

Baseline Sodium Lactate Injection (March 15, 2004)		Baseline Sodium Lactate Injection (May 10, 2004)		First Whey Injection (August 16, 2004)		Second Whey Injection (October 11, 2004)		Third Whey Injection (January 10, 2005)	
Sampling Events (Days after Injection)	Date of Sampling Events	Sampling Events (Days after Injection)	Date of Sampling Events	Sampling Events (Days after Injection)	Date of Sampling Events	Sampling Events (Days after Injection)	Date of Sampling Events	Sampling Events (Days after Injection)	Date of Sampling Events
2	3/16/04	2	5/11/04	2	8/17/04	2	10/12/04	2	1/11/05
4	3/18/04	4	5/13/04	4	8/19/04	4	10/14/04	4	1/13/05
8 to 10	3/22/04 to 3/24/04	8 to 10	5/17/04 to 5/19/04	8 to 10	8/23/04 to 8/25/04	8 to 10	10/18/04 to 10/20/04	8 to 9	1/17/05 to 1/18/05
						15	10/25/04	15	1/24/05
22	4/5/04	23	6/1/04	23	9/7/04	22	11/1/04	22	1/31/05
36 to 37	4/19/04 to 4/20/04	36 to 38	6/14/04 to 6/16/04	36 to 37	9/20/04 to 9/21/04	36 to 38	11/15/04 to 11/17/04	36 to 37	2/14/05 to 2/15/05
								50	2/28/05
		71 to 73	7/19/04 to 7/21/04			64 to 65	12/13/04 to 12/14/04	64 to 65	3/14/05 to 3/15/05
								78 to 79	3/28/05 to 3/29/05
								92 to 93	4/11/05 to 4/12/05
								106	4/25/05
								120 to 121	5/9/05 to 5/10/05
								135	5/24/05
								156 to 158	6/14/05 to 6/16/05

A-3.3.3 Analytical Parameters

In general, wells were sampled for electron donor, volatile organic compounds (VOCs), dissolved gases, and redox indicators on the high-frequency AED optimization sampling days (i.e., Days 2, 4, 15, 22, or 23), for all ISB parameters (INEEL 2003a) during the ISB monthly sampling events, and for VOCs, dissolved gases, and redox indicators on Days 78–79, 106, and 135 following the third whey powder injecton. Sample analyses were performed at the onsite field laboratory, at the INL Research Center (IRC), and at off-site laboratories (INEEL 2003b).

Difficulties with sample collection were encountered following the first whey powder injection due to foamy groundwater. The foamy groundwater made it impossible to fill sample bottles to no headspace; therefore, water was run over the top of the bottle in order to get the foam to dissipate, to achieve a meniscus on the top of the sample bottle when it was full, and to achieve no headspace. Despite the best sampling effort, no meniscus would form which made capping a bottle with no headspace extremely difficult to impossible. This was cause for concern for the ethene, ethane, and methane (E/E/M) samples since significant degassing could take place. Therefore, starting with the October 12, 2004, sampling event (the first sampling event following the second whey powder injection), modifications were made to the method for collecting E/E/M samples to improve the capture of the dissolved gases. The "new" sampling method was modified for use in the field from the technique normally conducted in the IRC laboratory. The modifications were performed immediately upon sample collection and included the following steps:

1. Tubing was placed on the end of the sample port
2. A glass syringe was secured to the tubing
3. The syringe was filled with groundwater and removed from the tubing
4. A disposable needle was attached to the end of the syringe
5. The needle was placed through the septum of a dissolved gases sample bottle
6. Groundwater contained in the syringe was injected into the dissolved gasses sample bottle
7. The bottle was inverted so that the water was in contact with the septum during sample storage and transportation to the IRC.

Samples were collected using both the "new" and the "old" methods for the remainder of the AED optimization to provide data to evaluate comparability of the two methods.

A-4. GROUNDWATER MONITORING RESULTS FOR THE AED OPTIMIZATION

Results of the groundwater monitoring performed during the AED optimization are reported in this section. Section A-4.1 discusses the fate and transport of both sodium lactate and whey powder following the electron donor injections. Geochemical conditions, including redox conditions, biological activity indicators, and water quality data are presented in Section A-4.2. Section A-4.3 presents the efficiency of ARD reactions following both sodium lactate and whey powder injections. Radiological monitoring results are presented in Section A-4.4, microbial characterization in Section A-4.5, quality assurance in Section A-4.6, and cost in Section A-4.7.

A-4.1 Electron Donor

Understanding the fate of the electron donor substrate, the degradation pathways (Section A-4.1.1), and the electron donor distribution and degradation (Section A-4.1.2) and utilization (Section A-4.1.3) are important considerations in assessing ISB performance. Not all substrates are equally effective in stimulating ARD, and an accurate model of the fate of the electron donor is useful in determining which electron donor may be more effective at a particular site.

A-4.1.1 Electron Donor Degradation Pathways

The anaerobic fermentation of lactate, and lactose (the primary constituent of whey powder), generate volatile fatty acids, such as propionate and acetate, and molecular hydrogen (H_2). Many anaerobic dechlorinators, including *Dehalococcoides*, use these degradation by-products as sources of carbon and electrons during growth (Scholz-Muramatsu et al., 1995; Holliger et al., 1992; Maymo-Gatell et al., 1997). Therefore, the fate of the primary constituents to secondary products is an important consideration for the in situ stimulation of ARD.

A-4.1.1.1 Sodium Lactate. The anaerobic degradation of lactate proceeds via two primary pathways, the acetate pathway (Equation A-1 [He et al. 2002]) and the propionate pathway (Equation A-2 [He et al. 2002]):

$$\text{lactate}^- + 2H_2O \rightarrow \text{acetate}^- + HCO_3^- + 2H_2 + 2H^+ \quad \text{(A-1)}$$

$$3\ \text{lactate}^- \rightarrow 2\ \text{propionate}^- + \text{acetate}^- + HCO_3^- + 2H^+ \ . \quad \text{(A-2)}$$

The acetate pathway involves the degradation of lactate to acetate, bicarbonate, and free hydrogen, while the propionate pathway degrades lactate to propionate, acetate, and bicarbonate. The propionate pathway does not produce free hydrogen directly but rather the degradation of the secondary product, propionate, generates acetate, carbonate, and free hydrogen (Equation A-3 [Fennel and Gossett 1998]). Under extremely reducing conditions, acetate, which is produced during the fermentation of both lactate and propionate, can be further oxidized to bicarbonate and hydrogen, via Equation A-4 (He et al. 2002):

$$\text{propionate}^- + 3H_2O \rightarrow \text{acetate}^- + HCO_3^- + 3H_2 + 3H^+ \quad \text{(A-3)}$$

$$\text{acetate}^- + 4H_2O \rightarrow 2HCO_3 + 4H_2 + H^+ \ . \quad \text{(A-4)}$$

A-4.1.1.2 Whey Powder. While the conceptual model for the degradation of sodium lactate is well defined and easily tracked in the field, whey powder is significantly more complex. The grade of whey powder selected for the AED optimization is composed of 70 to 75% lactose, 10 to 13% protein, and 7 to 13% ash. The degradation pathways for whey are not well defined or described in the literature. However, a multitude of daughter products have been reported as a result of the anaerobic fermentation of whey, including acetate, propionate, butyrate, iso-butyrate, valerate, caproate, lactate, ethanol, propanol, and others (Kissalita et al. 1989; Fang et al. 2001). These daughter products serve as secondary substrates providing a long term source of additional carbon and hydrogen. While these studies identified potential degradation daughter products, those specifically resulting from the injection of whey powder into groundwater at TAN were evaluated first by observing the production of daughter products after a whey injection. Once the fermentation products were identified, then specific degradation pathways that could be responsible for the production of the products were identified from the literature. The secondary substrates observed at TAN following whey injection included acetate, propionate, butyrate, and low levels of isobutyrate, isovalerate, valerate, and hexanoate.

Injection of whey powder at TAN resulted in the production of several volatile fatty acids. Figure A-2 illustrates the known pathways for microbial degradation of lactose and its associated fermentation products. As lactose is initially degraded anaerobically, it is either hydrolyzed into glucose and galactose or proceeds directly to the production of hydrogen. The production of glucose and galactose provides substrate for additional anaerobic fermentation processes, some of which were considered (Madigan et al. 1997) and are described in the following equations:

$$\text{glucose} + 2H_2O \rightarrow \text{butyrate}^- + 2HCO^-_3 + 3H^+ + 3H_2 \quad \text{(A-5)}$$

$$\text{glucose} + 4H_2O \rightarrow 2\ \text{acetate}^- + 2HCO^-_3 + 4H^+ + 4H_2 \quad \text{(A-6)}$$

$$\text{glucose} + 2H_2O \rightarrow \text{acetate}^- + \text{pyruvate}^- + HCO^-_3 + 3H^+ + 3H_2 \quad \text{(A-7)}$$

$$\text{glucose} + 2H_2O \rightarrow \text{isobutyrate} + 2HCO_3^- + 3H^+ + 2H_2 \quad \text{(A-8)}$$

$$\text{glucose} + 5H_2O \rightarrow \text{propionate} + 3HCO_3^- + 2H^+ + 3H_2 \quad \text{(A-9)}$$

$$\text{glucose} + 12H_2O \rightarrow 6HCO^-_3 + 6H^+ + 12H_2\ . \quad \text{(A-10)}$$

At TAN, the glucose and galactose were rapidly fermented into a variety of secondary substrates, including propionate, acetate, and butyrate. These secondary fermentation products were fermented further to produce acetate and/or hydrogen (acetate and propionate oxidation is outlined in Section A-4.1.1.1). Production of hydrogen from butyrate is shown in Equation A-11 (He et al. 2002):

$$\text{butyrate}^- + 2H_2O \rightarrow 2\ \text{acetate}^- + H^+ + 2H_2\ . \quad \text{(A-11)}$$

A conceptual model of whey powder degradation, based on the knowledge gathered from current literature, includes the production and utilization of the primary substrate lactose, with production of primarily butyrate, acetate and propionate. These secondary substrates serve as a long term source of additional carbon and hydrogen. Ultimately, fermentation of the primary and secondary substrates results in the production of dissolved hydrogen, which is the electron donor used by *Dehalococcoides*, the dehalogenating bacteria identified at TAN capable of complete ARD of TCE to ethene. Understanding these pathways facilitates the interpretation of electron donor distribution and degradation (Section A-4.1.2) and utilization (Section A-4.1.3). These data will be used to assess the performance of whey powder relative to sodium lactate for enhanced ISB at TAN.

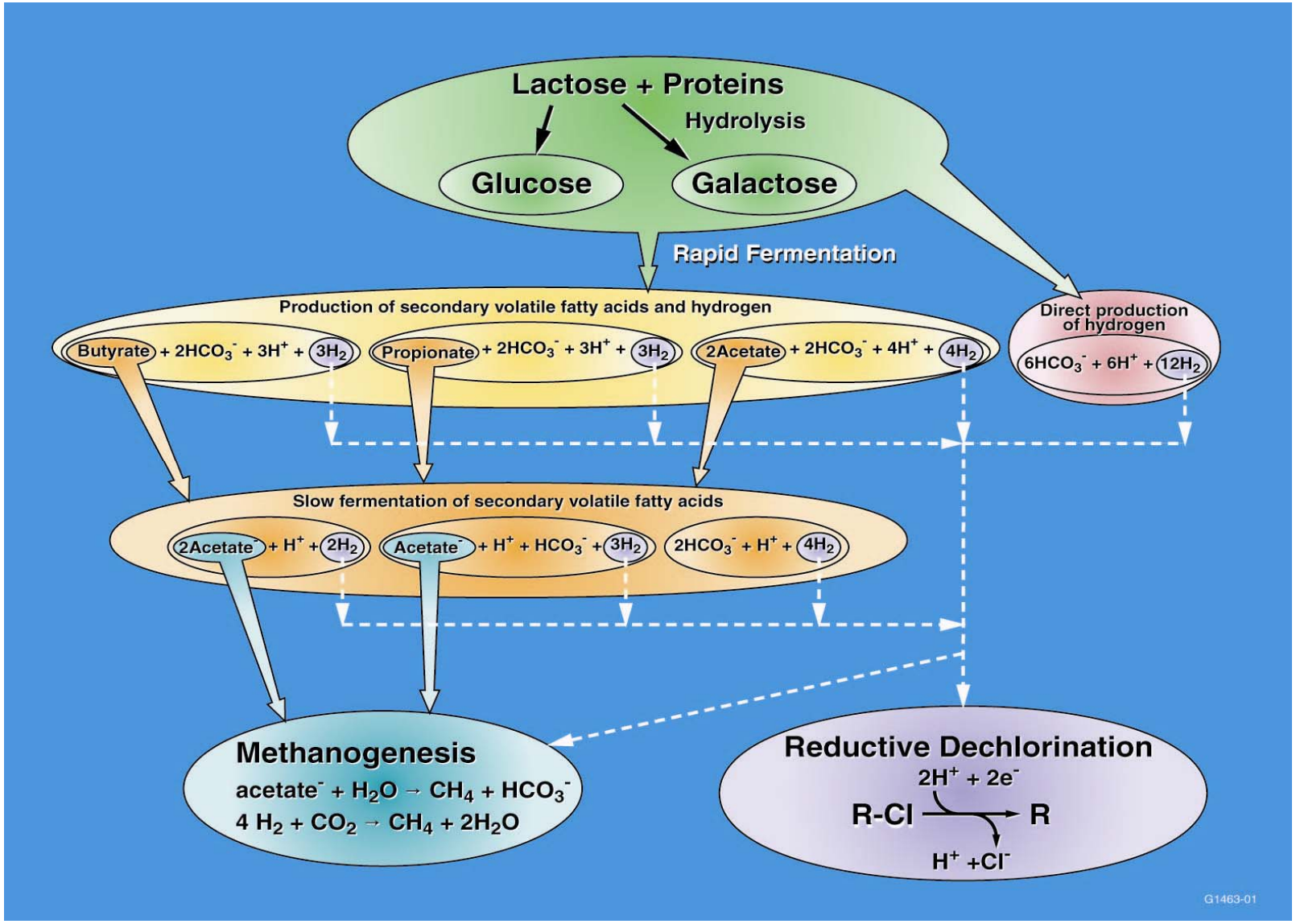

Figure A-2. Microbial utilization pathways of lactose and its fermentation products.

A-4.1.2 Electron Donor Distribution and Degradation

This section describes the distribution and degradation of electron donor following each injection event. The amount of electron donor distributed was assessed by high-frequency sampling of the AED wells TSF-05A, TSF-05B, TAN-25 and TAN-31, and TAN-1859. TAN-1859 was sampled during regular ISB operations during the sodium lactate and the first and second whey powder injection cycles, and was included in the high frequency AED sampling for the third whey powder injection cycle. These data provide a high-resolution picture of distribution. Chemical oxygen demand (COD) was also measured as an indicator of total electron donor. The concentrations of COD, the primary substrates lactate and lactose, and the secondary degradation products were used to determine the distribution of electron donor impact from the injection well.

A-4.1.2.1 Distribution of Electron Donor Following Sodium Lactate Injections at 1X 6%.

Sodium lactate injections with high frequency sampling were performed March 15, 2004, and May 10, 2004. On Days 2 and 4 following the first sodium lactate injection (March 15, 2004), lactate and COD concentrations were the highest ever observed over the 6 years ISB has been implemented in the residual source area at TSF-05B (15,200 and 10,300 mg/L, respectively), TAN-25 (14,800 and 9,600 mg/L, respectively), TSF-05A (10,700 and 9,200 mg/L, respectively), and TAN-31 (4,500 and 4,400 mg/L, respectively). Figure A-3 shows the COD concentration versus time for all AED wells, and Figures A-4 through A-7 show the individual electron donor concentrations versus time. After the second sodium lactate injection (May 10, 2004), lactate and COD concentrations were generally higher than those observed after the first sodium lactate injection. Lactate and COD concentrations were the highest in TAN-25 (16,500 and 13,500 mg/L, respectively), followed by TSF-05B (16,000 and 11,200 mg/L, respectively), TSF-05A (14,900 and 11,400 mg/L, respectively), and then TAN-31 (6,500 and 5,800 mg/L, respectively).

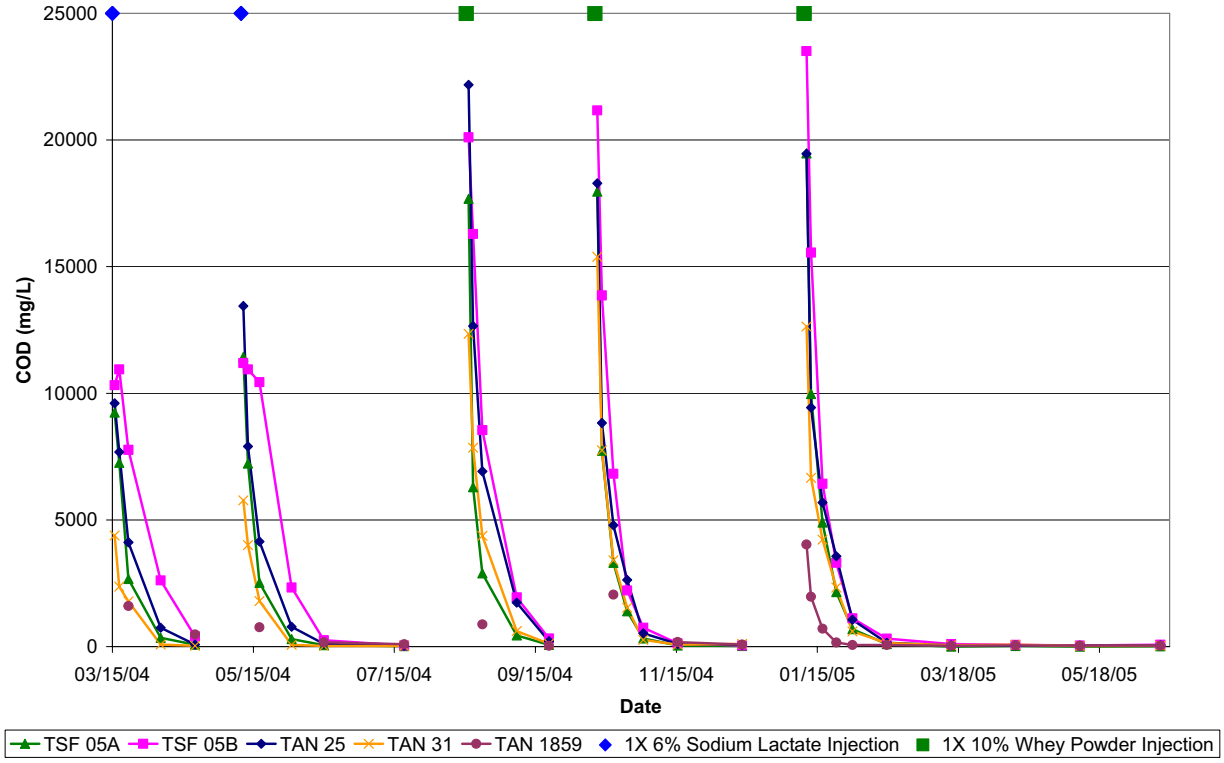

Figure A-3. Chemical oxygen demand concentrations at the alternate electron donor wells.

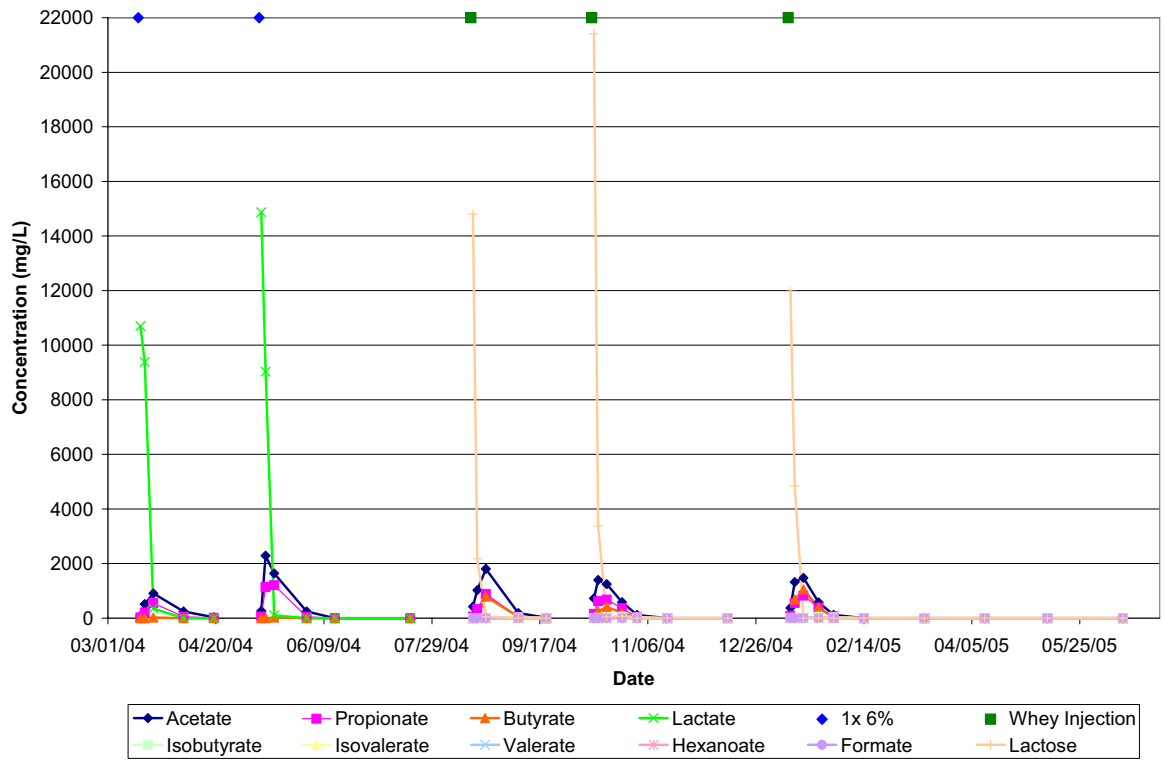

Figure A-4. Electron donor concentrations at TSF-05A.

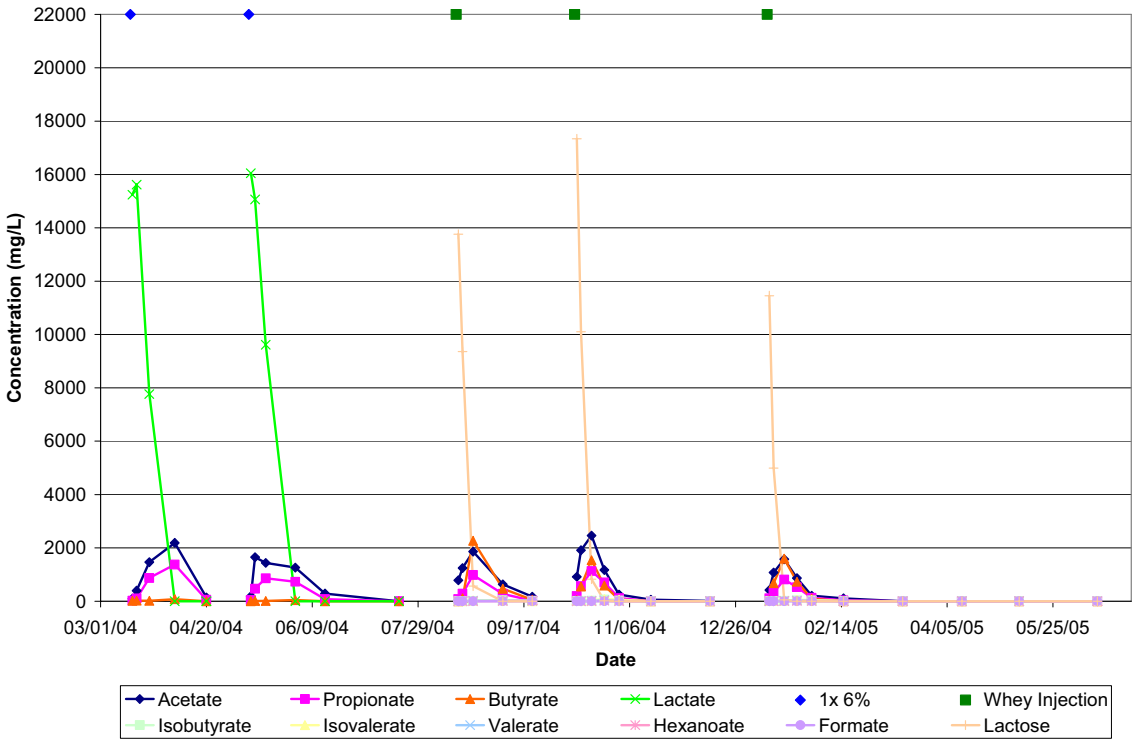

Figure A-5. Electron donor concentrations at TSF-05B.

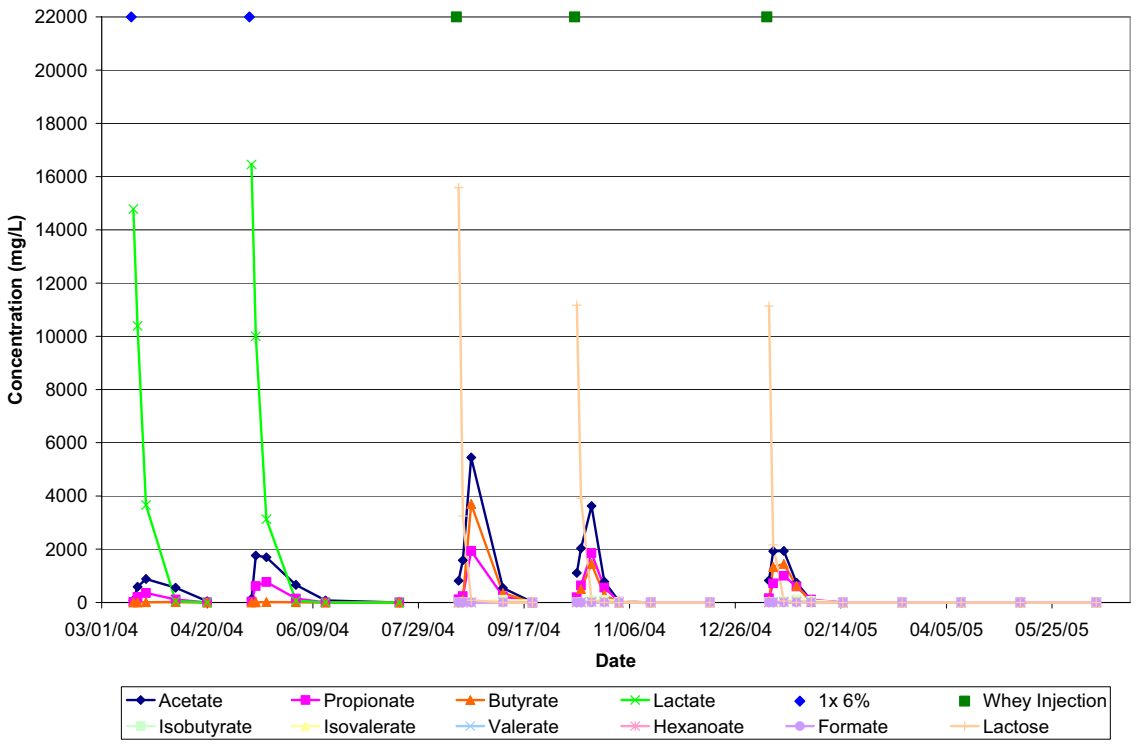

Figure A-6. Electron donor concentrations at TAN-25.

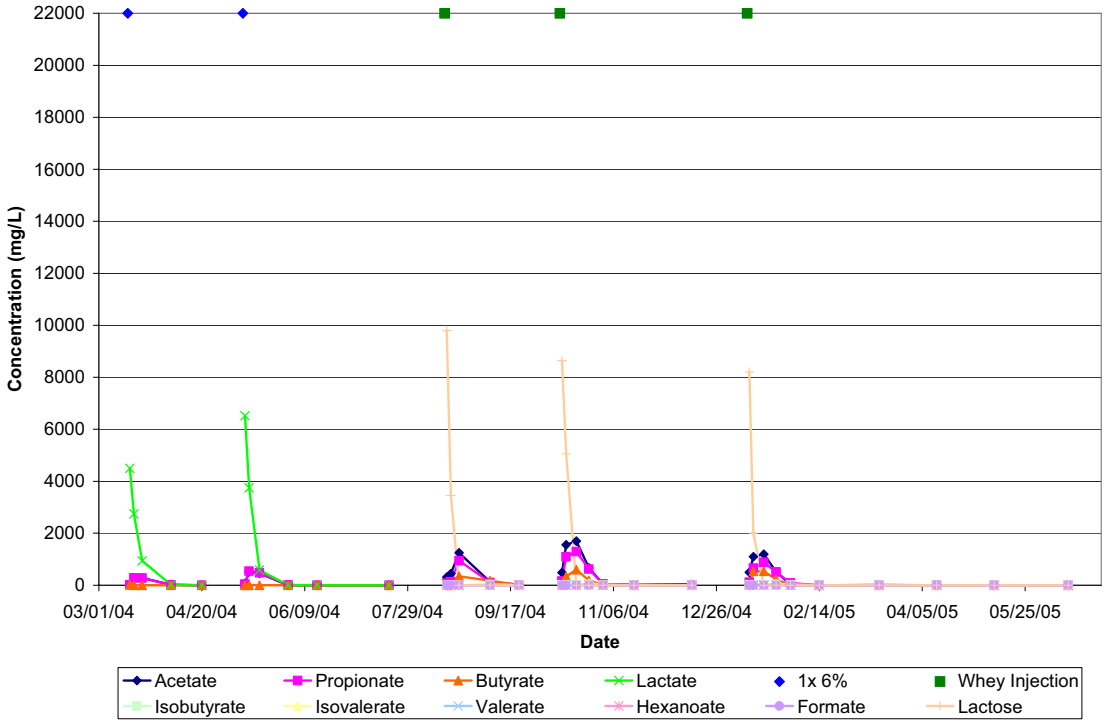

Figure A-7. Electron donor concentrations at TAN-31.

Electron donor was also distributed to TAN-1859, approximately 90 ft downgradient of the injection well (TSF-05). Approximately 1 week after the first sodium lactate injection, TAN-1859 had COD and lactate concentrations of 1,600 and 380 mg/L, respectively, and 1 week after the second sodium lactate injection, concentrations of 760 and 103 mg/L, respectively, were observed. The higher COD concentration observed following the first lactate injection was likely a result of residual impacts from the lactate injection that occurred in TAN-1859 on February 9, 2004. It is likely that electron donor was still present at TAN-1859 at the time of injection into TSF-05 on March 15, 2004 (the start of the AED optimization). Figure A-8 shows the molar concentration of the electron donor at TAN-1859 during the AED optimization.

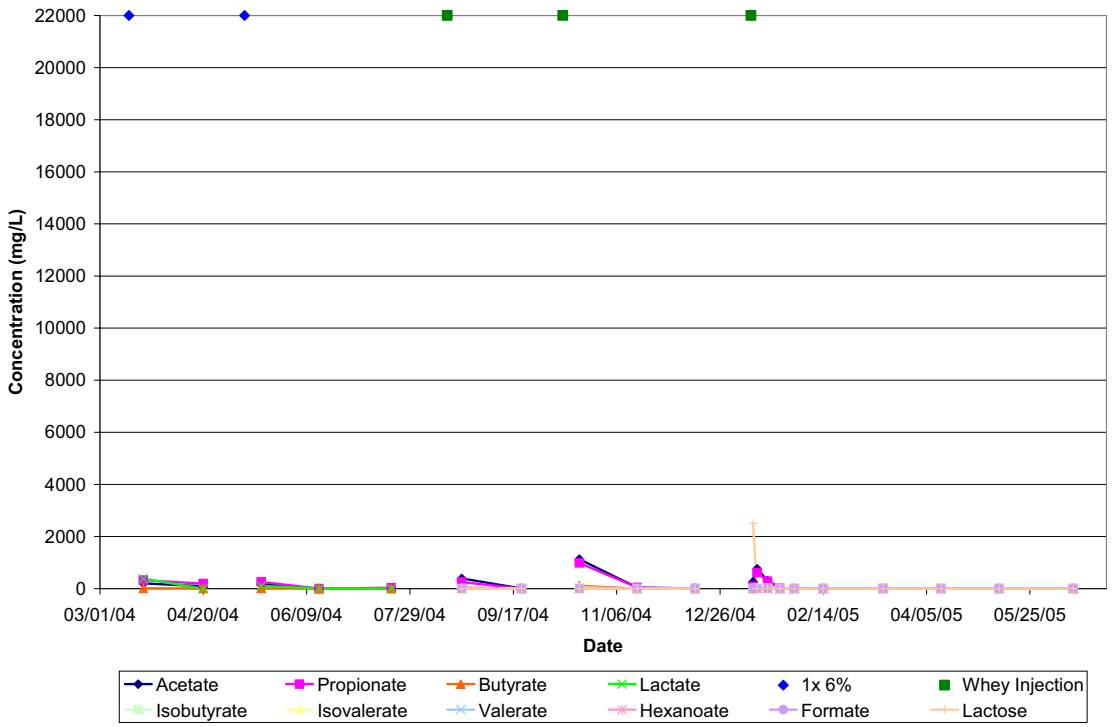

Figure A-8. Electron donor concentrations at TAN-1859.

A-4.1.2.2 Degradation of Sodium Lactate Following Injections at 1X 6%. As described in Section A-4.1.1, lactate utilization results in the production of the secondary products propionate and acetate, which provide essential nutrients and increase the overall longevity of lactate as an electron donor for ARD. Accordingly, following each sodium lactate injection, concentrations of these degradation products increased in all of the AED wells. The mass and molar concentrations of lactate and its fermentation byproducts in the AED wells following the first and second 1X 6% sodium lactate injections are presented in Tables A-6 and A-7.

Fermentation of lactate at TAN occurs via both pathways, with accumulation of both acetate and propionate in all of the AED wells (Tables A-6 and A-7). Following a lactate injection, the propionate to acetate ratios within these wells was less than one (Table A-6). A propionate to acetate ratio of 1 suggests that for every four moles of lactate degraded, two moles of propionate and two moles of acetate are produced. Therefore, to achieve a ratio of 0.5 for instance (TSF-05 by Day 8–10), three moles of lactate would be degraded via the acetate pathway and three moles of lactate would be degraded via the propionate pathway. Therefore, the lactate utilized in the TAN system is degraded nearly equally between both pathways (Tables A-6 and A-7).

Table A-6. Electron donor data for the 1X 6% sodium lactate injection on March 15, 2004, in TSF-05.

Well	Sampling Event (Day)	COD (mg/L)	Lactate (mg/L) Molar %	Propionate (mg/L) Molar %	Acetate (mg/L) Molar %	Butyrate (mg/L) Molar %	Propionate: Acetate (molar)
TSF-05A	2	9,200	10,700 99%	21[b] 0%	69 1%	0[c] 0%	0.24
TSF-05A	4	7,300	9,400 90%	206 2%	514 8%	0[c] 0%	0.32
TSF-05A	8	2,700	350 14%	550 28%	905 57%	21 1%	0.49
TSF-05A	22	350	0[a] 0%	50 14%	240 85%	0[c] 0%	0.16
TSF-05A	36	75	0[a] 0%	12 20%	36 77%	0[c] 3%	0.26
TSF-05B	2	10,300	15,200 99%	24[b] 0%	95 1%	19[b] 0%	0.21
TSF-05B	4	10,900	15,600 95%	102 1%	400 4%	21[b] 0%	0.21
TSF-05B	10	7,767	7,800 70%	870 10%	1,500 20%	15[b] 0%	0.48
TSF-05B	22	2,610	2[b] 0%	1,400 33%	2,200 65%	77 2%	0.51
TSF-05B	37	400	0[a] 0%	56 24%	144 75%	0[c] 0%	0.31
TAN-25	2	9,600	14,800 99%	24[b] 0%	82 1%	0[c] 0%	0.24
TAN-25	4	7,700	10,400 90%	203 2%	590 8%	0[c] 0%	0.28
TAN-25	8	4,100	3,700 67%	360 8%	885 25%	13[b] 0%	0.33
TAN-25	22	740	50 5%	112 13%	560 81%	17 1%	0.16
TAN-25	37	82	0[a] 0%	0[a] 0%	46 100%	0[c] 0%	0.04
TAN-31	2	4,400	4,500 98%	23 1%	36 1%	19[b] 0%	0.52
TAN-31	4	2,400	2,800 78%	280 10%	275 12%	0[c] 0%	0.83
TAN-31	10	1,800	940 55%	270 20%	290 25%	0[c] 0%	0.79
TAN-31	22	77	15 24%	16 32%	18 44%	0[c] 0%	0.72
TAN-31	37	28	0[a] 0%	0[c] 0%	0[c] 0%	0[c] 0%	0.81

Table A-6. (continued).

Well	Sampling Event (Day)	COD (mg/L)	Lactate (mg/L) Molar %	Propionate (mg/L) Molar %	Acetate (mg/L) Molar %	Butyrate (mg/L) Molar %	Propionate: Acetate (molar)
TAN-1859	8	1,600	380 35%	330 36%	206 28%	11 1%	1.29
TAN-1859	37	480	0[a] 0%	200 61%	90 35%	13 4%	1.76

a. These values were reported as <0.223, which means that lactate was detected but was below the method detection limit (MDL). These values are therefore reported here as 0 mg/L.
b. Although there are volatile fatty acids (VFAs) present, when the molar percentage was calculated, the percent of the VFA was so small that 0% was recorded.
c. Value reported as <5 mg/L, which means that the VFA was detected but was below the MDL. These values are therefore reported here as 0 mg/L.

Table A-7. Electron donor data for the 1X 6% sodium lactate injection on May 10, 2004, in TSF-05.

Well	Time Elapsed After Injection (Days)	COD (mg/L)	Lactate (mg/L) Molar %	Propionate (mg/L) Molar %	Acetate (mg/L) Molar %	Butyrate (mg/L) Molar (%)	Propionate: Acetate (molar)
TSF-05A	2	11,400	14,900 97%	59 1%	258 2%	0[c] N/A	0.19
TSF-05A	4	7,200	9,000 65%	1,100 10%	2,300 25%	0[c] 0%	0.40
TSF-05A	8	2,500	105 3%	1,200 36%	1,600 61%	22[b] 0%	0.59
TSF-05A	23	295	1[b] 0%	54 15%	241 84%	0[c] 0%	0.18
TSF-05A	36	56	0[a] 0%	0[c] 0%	0[c] 0%	0[c] 0%	0.81
TSF-05A	71	19	0[a] 0%	0[c] 0%	0[c] 0%	0[c] 0%	0.81
TSF-05B	2	11,200	16,000 98%	43[b] 0%	185 2%	0[c] 0%	0.19
TSF-05B	4	10,900	15,000 83%	467.7 3%	1,653.8 14%	9[b] 0%	0.23
TSF-05B	9	10,400	9,600 75%	860 8%	1,400 17%	12[b] 0%	0.48
TSF-05B	23	2,300	0[a] 0%	730 31%	1,300 67%	46 2%	0.47
TSF-05B	37	251	0[a] 0%	78 18%	287 82%	0[c] 0%	0.22
TSF-05B	72	44	0[a] 0%	0[c] 0%	0[c] 0%	0[c] 0%	0.81
TAN-25	2	13,500	16,500 99%	34[b] 0%	137 1%	0[c] 0%	0.20

Table A-7. (continued).

Well	Time Elapsed After Injection (Days)	COD (mg/L)	Lactate (mg/L) Molar %	Propionate (mg/L) Molar %	Acetate (mg/L) Molar %	Butyrate (mg/L) Molar (%)	Propionate: Acetate (molar)
TAN-25	4	7,900	10,000 74%	617 6%	1,800 20%	6[b] 0%	0.28
TAN-25	9	4,100	3,100 47%	770 14%	1,700 39%	16 1%	0.37
TAN-25	23	781	63 5%	150 14%	663 80%	13 1%	0.18
TAN-25	37	103	0[a] 0%	0[c] 0%	73 100%	0[c] 0%	0.03
TAN-25	72	36	0[a] 0%	0[c] 0%	0[c] 0%	0[c] 0%	0.81
TAN-31	2	5,800	6,500 98%	46 1%	65 1%	0[c] 0%	0.57
TAN-31	4	4,000	3,800 72%	550 13%	520 15%	0[c] 0%	0.85
TAN-31	9	1,800	580 31%	480 31%	461 37%	0[c] 0%	0.84
TAN-31	23	66	4 24%	13 76%	0[c] 0%	0[c] 0%	4.30
TAN-31	37	23	0[a] 0%	0[c] 0%	0[c] 0%	0[c] 0%	0.81
TAN-31	72	26.5	0[a] 0%	0[c] 0%	0[c] 0%	0[c] 0%	0.81
TAN-1859	9	759	103 15%	261 46%	180 38%	9 1%	1.19
TAN-1859	37	168	0[a] 0%	0[c] 0%	0[c] 0%	0[c] 0%	0.81
TAN-1859	72	95	0[a] 0%	33 79%	9 21%	0[c] 0%	2.99

a. These values were reported as <0.223, which means that lactate was detected but was below the MDL. These values are therefore reported here as 0 mg/L.
b. Although lactate or butyrate was present, when the molar percentage was calculated, the percent lactate was so small that 0% was recorded.
c. Value reported as <5 mg/L, which means that the VFA was detected but was below the MDL. These values are therefore reported here as 0 mg/L.

Molecular characterization of TAN groundwater seven days after a lactate injection supports these findings and reveals a bacterial community predominated by fermentative and homoacetogenic *Clostridia* (Macbeth et al. 2005). The majority of these *Clostridia*, however, were associated with the lactate to acetate pathway. In addition, the majority of methanogens detected were acetate-utilizing methanogens and not hydrogen-utilizing, suggesting that the acetate generated from both lactate and propionate utilization is more influential in terms of electron transfer in methanogens than hydrogen. Competition for hydrogen does not appear to be a driving factor influencing ARD performance. This is supported by field and laboratory data, which show high rates of TCE degradation to ethene (Macbeth et al. 2005) under conditions where high concentrations of lactate are amended.

As shown in Tables A-6 and A-7, lactate concentrations were the highest at TSF-05B (15,200 mg/L), TAN-25 (14,800 mg/L), TSF-05A (10,700 mg/L), and TAN-31 (4,400 mg/L) the day after (Day 2) the March 2004 injection. By Days 8–10 following the injection, propionate and acetate concentrations were the highest observed over the injection cycle at TSF-05A (550 and 905 mg/L, respectively), TSF-05B (870 and 1,500 mg/L, respectively), TAN-25 (360 and 885 mg/L, respectively), and TAN-31 (270 and 290 mg/L, respectively). Lactate concentrations, however, were still higher than propionate and acetate at TSF-05B (7,800 mg/L), TAN-25 (3,700 mg/L), and TAN-31 (940 mg/L). TSF-05A had lower lactate concentrations (350 mg/L) than the propionate and acetate concentrations by the Day 8–10 sampling event. By the Day 22 or 23 sampling event, lactate was depleted in TSF-05A and TSF-05B and significantly reduced at TAN-25 (50 mg/L) and TAN-31 (15 mg/L). The electron donors were further depleted by the Days 36–38 sampling event, with only propionate and acetate present at TSF-05A (12 and 36 mg/L, respectively) and TSF-05B (56 and 144 mg/L, respectively) and only acetate present at TAN-25 (46 mg/L). No electron donor was present at TAN-31 by Days 36–38.

Tables A-6 and A-7 also present the concentration of electron donors distributed to TAN-1859. This well was only sampled during regular ISB sampling events, which fell on Days 8–10 and 36–38 after each lactate injection, and then an additional sampling event on Days 71–73 after the second lactate injection. The week after the March 2004 sodium lactate injection, lactate concentrations were 380 mg/L, propionate concentrations were 330 mg/L, and acetate concentrations were 206 mg/L. By the Days 36–38 sampling event, the lactate concentration was non-detect at TAN-1859, and propionate and acetate concentrations were 200 mg/L and 90 mg/L, respectively.

Figures A-9 through A-13 illustrate the molar concentrations of the volatile fatty acids (VFAs) for all of the AED wells. The mole fractions of lactate, propionate, and acetate illustrate the conversion of lactate to propionate and acetate and then from propionate to acetate. The day after injection, all electron donors were present as lactate (98 to 99%) at all of the AED well locations. By Days 8–10, however, propionate and acetate production was evident by increasing mole percentages of propionate and acetate at TSF-05A (28 and 57%, respectively), TSF-05B (10 and 20%, respectively), TAN-25 (8 and 25%, respectively) and TAN-31 (20 and 25%, respectively). However, lactate remained the major VFA at TSF-05B and TAN-25 (70 and 67%, respectively) at that sampling event (Days 8–10). By Day 22 or 23, lactate was no longer found at TSF-05A and TSF-05B, and propionate and acetate mole percentages were 14 and 85% in TSF-05A and 33 and 65% in TSF-05B. TAN-25 still had low concentrations of lactate (50 mg/L and 5% molar) but much higher propionate (112 mg/L and 13% molar) and acetate (560 mg/L and 81% molar). TAN-31 was essentially depleted of electron donor by Day 22 or 23 (15 mg/L lactate, 16 mg/L propionate, and 18 mg/L acetate). By Days 36–38, the total electron donor had been significantly depleted at TSF-05A and TSF-05B, with concentrations <40 mg/L for the major VFAs. TAN-25 had only low concentrations of acetate (46 mg/L) and TAN-31 had no electron donor.

The May 2004 response following sodium lactate injection was similar to the response following the March 2004 injection at the AED well locations. Lactate was converted to propionate and acetate, as was evident by the generation of significant amounts of propionate and acetate 1 week (Days 8–10) following the injection at TSF-05A (1,200 and 1,600 mg/L, respectively), TSF-05B (860 and 1,400 mg/L, respectively), TAN-25 (770 and 1,700 mg/L, respectively), and TAN-31 (480 and 461 mg/L, respectively). By the Day 22 or 23 sampling event, acetate was the major VFA remaining, with concentrations and molar percentages at 241 mg/L and 84% at TSF-05A, 1,300 mg/L and 67% at TSF-05B, and 663 mg/L and 80% at TAN-25. Electron donor was depleted in TAN-31 at the Day 22 or 23 sampling event. No electron donor remained at TSF-05A and TAN-31 by the Days 36–38 sampling event; 78 mg/L propionate and 287 mg/L acetate were present at TSF-05B, and 73 mg/L acetate was present at TAN-25. At the Days 71–73 sampling event, no electron donor was present at any of the AED wells.

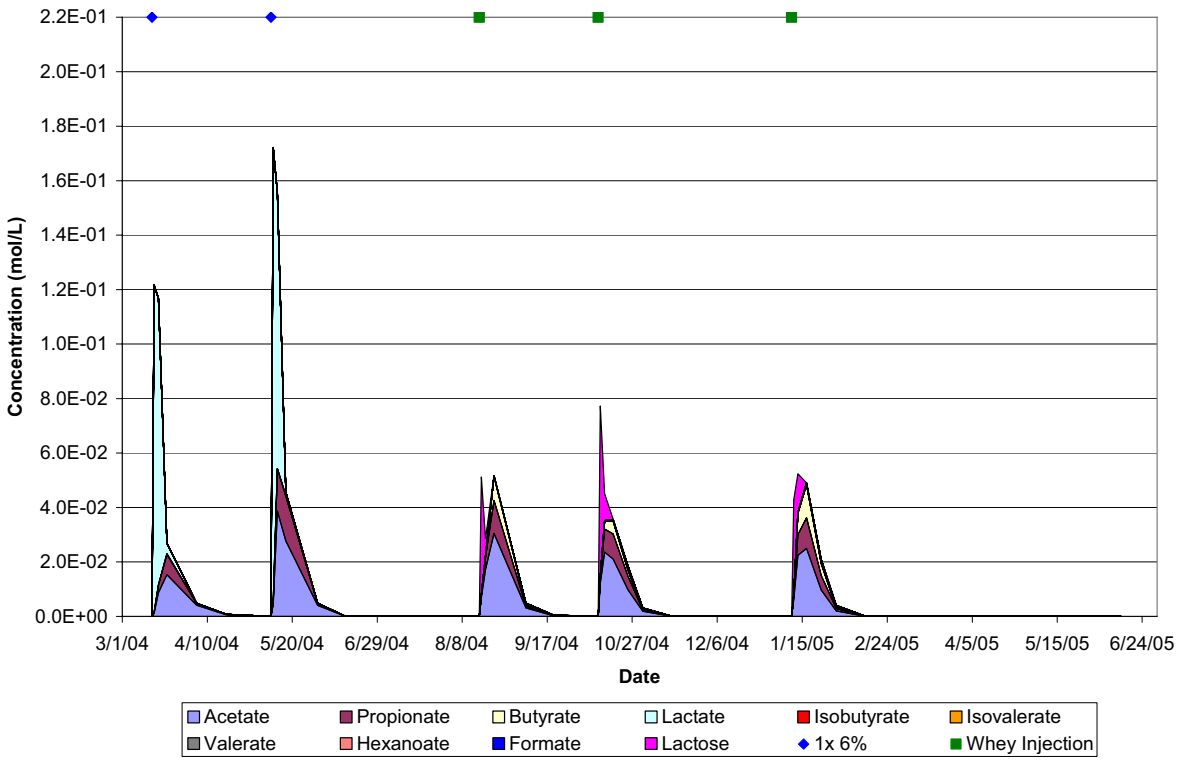

Figure A-9. Electron donor molar concentrations at TSF-05A.

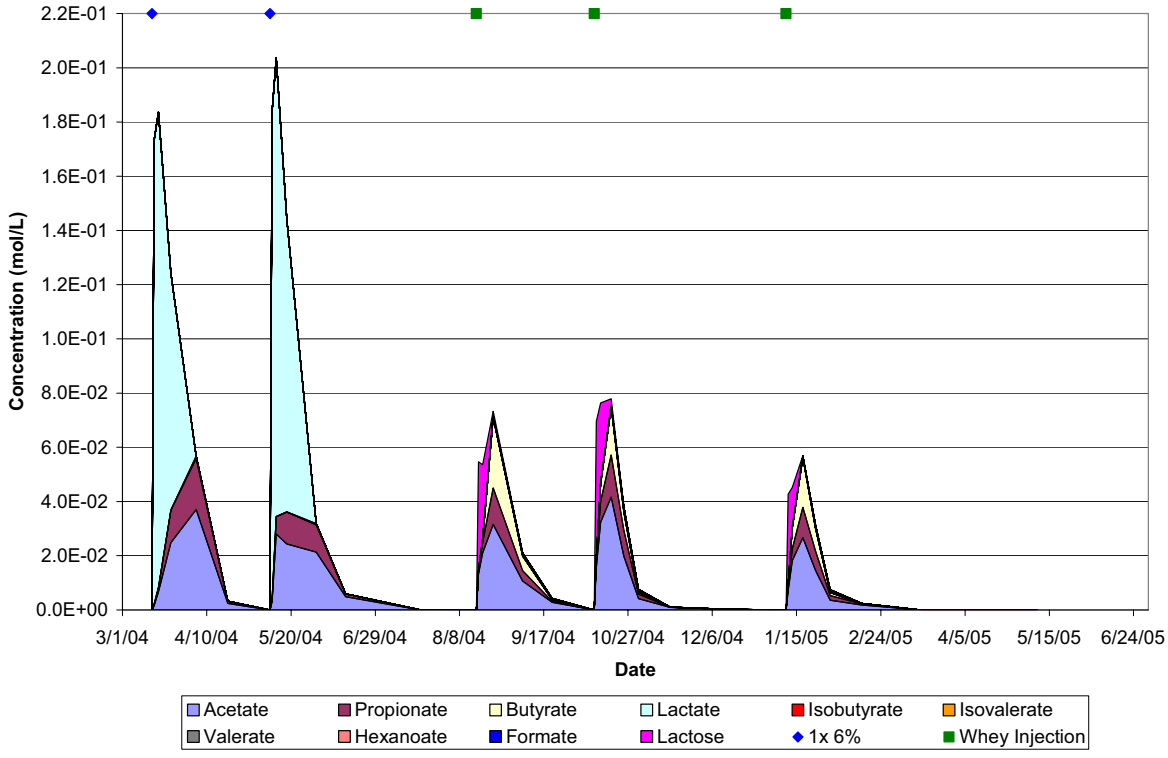

Figure A-10. Electron donor molar concentrations at TSF-05B.

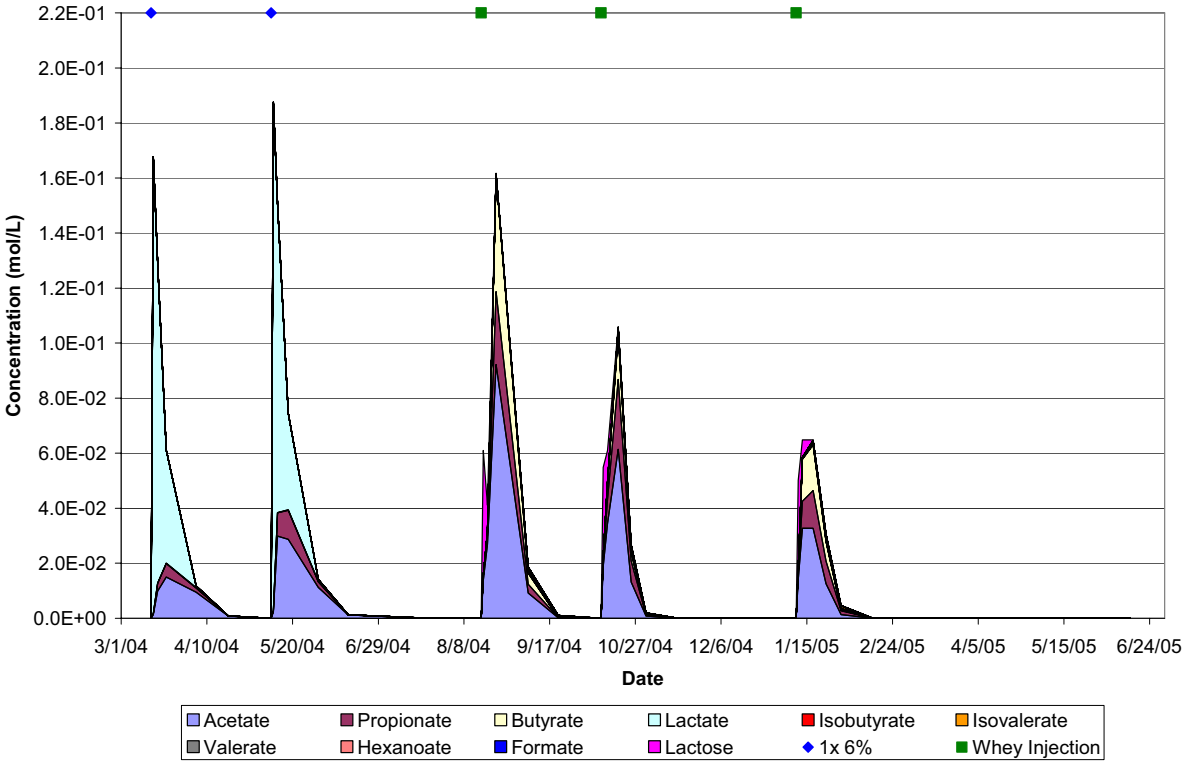

Figure A-11. Electron donor molar concentrations at TAN-25.

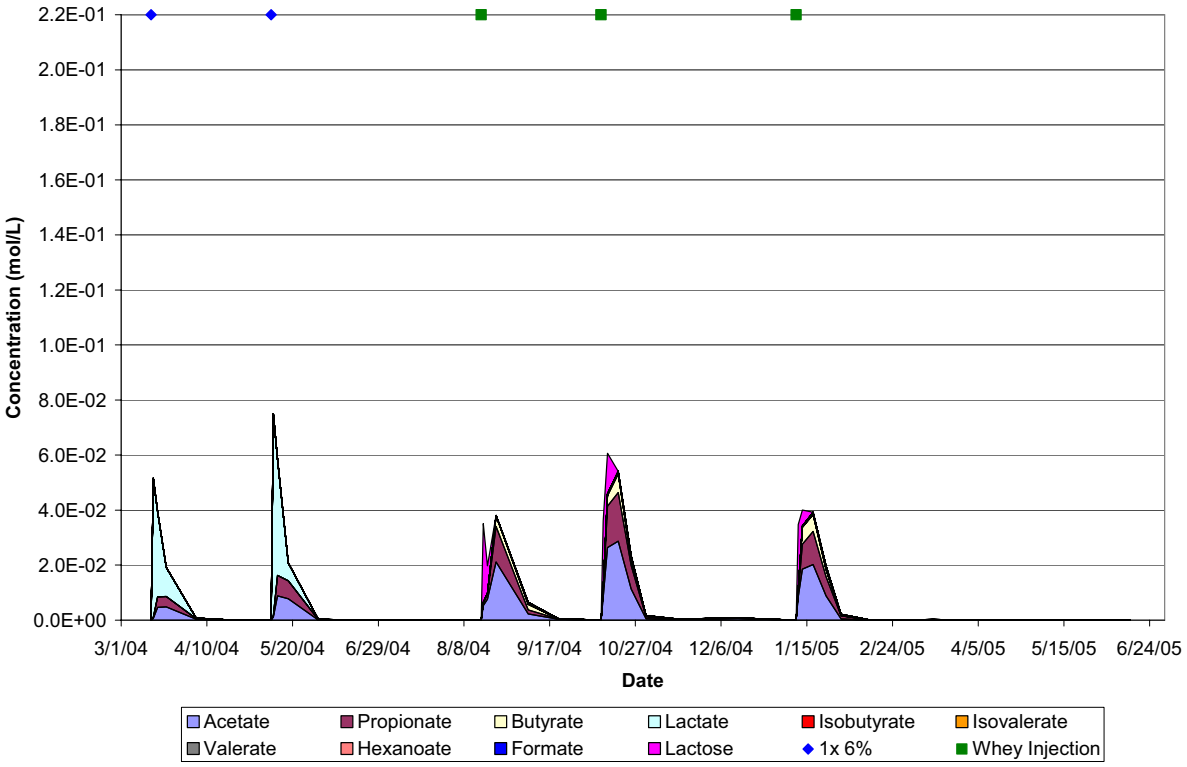

Figure A-12. Electron donor molar concentrations at TAN-31.

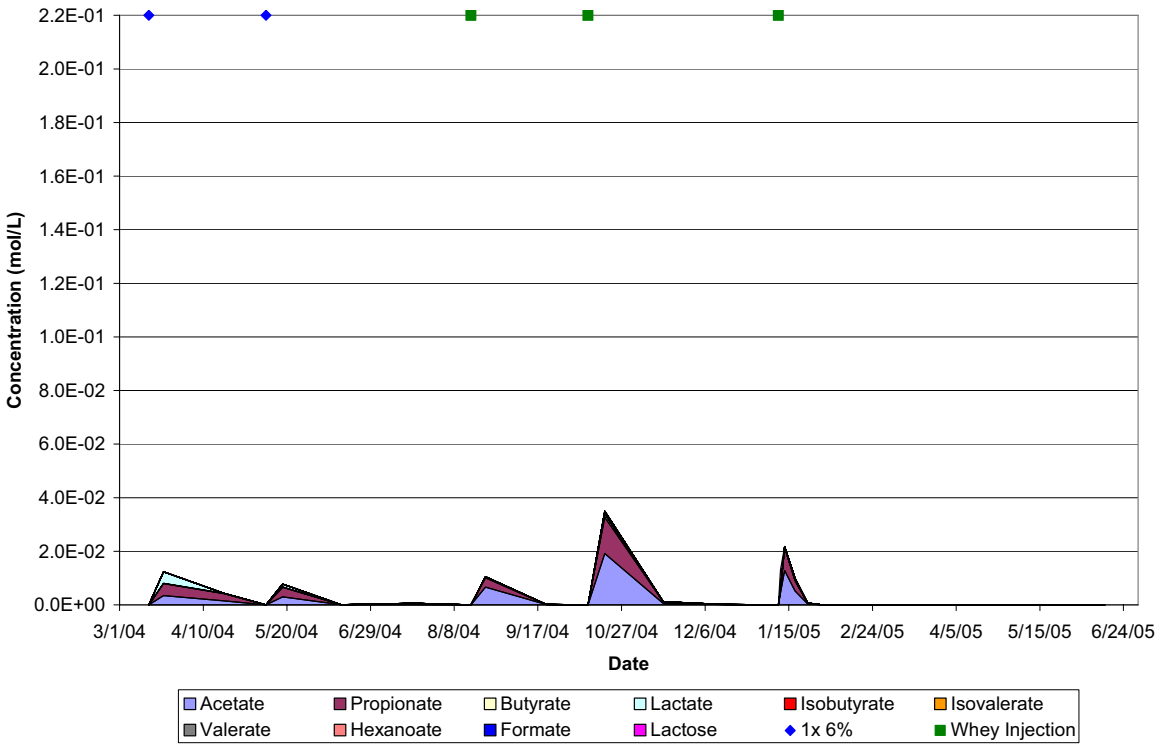

Figure A-13. Electron donor molar concentrations at TAN-1859.

Lactate concentrations at TAN-1859 were 103 mg/L one week after the May 2004 lactate injection. In addition, propionate concentrations were 261 mg/L and acetate concentrations were180 mg/L. By Days 36–38 following the second lactate injection, lactate, propionate, and acetate were all non-detect. On Days 71–73 after the second lactate injection, propionate and acetate were detected with concentrations at 33 and 9 mg/L, respectively.

A-4.1.2.3 Distribution of Electron Donor Following the Whey Powder Injection 1X 10%.

The first whey powder injection occurred on August 16, 2004. The injection concentration of whey powder (10%) was higher than that of sodium lactate (6%). Consequently, COD concentrations at the AED wells were much higher following the whey powder injection (20,000 mg/L in TSF-05B) than COD concentrations observed after the sodium lactate injections (10,000 to 11,000 mg/L in TSF-05B) (Table A-8). Higher concentrations of COD were also observed at TSF-05A (17,700 vs. 9,000 to 11,000 mg/L), TAN-25 (22,000 vs. 13,000 mg/L), and TAN-31 (12,000 vs. 5,800 mg/L) the day after injection. COD concentrations at TAN-1859 were approximately 880 mg/L after the whey powder injection, which is slightly higher than the COD concentrations (760 mg/L) observed at this well after the second lactate injection.

Whey powder is comprised of approximately 70% w/w lactose; therefore, high concentrations of lactose were observed at TAN-25 (15,600 mg/L), TSF-05A (14,800 mg/L), TSF-05B (13,800 mg/L), and TAN-31 (9,800 mg/L) the day after the whey powder injection (Table A-8). By the Day 4 sampling event, lactose concentrations had significantly declined at TSF-05B (9,400 mg/L), TAN-25 (3,200 mg/L), TAN-31 (3,500 mg/L), and TSF-05A (2,200 mg/L). By the Days 8–10 sampling event, lactose concentrations were depleted at all monitoring locations except for TSF-05B (~500 mg/L). However, by Days 8–10, propionate and acetate production was evident by increasing mole percentages of propionate and acetate at TSF-05A (23 and 59%, respectively), TSF-05B (19 and 44%, respectively), TAN-25 (16 and 57%, respectively) and TAN-31 (34 and 56%, respectively). By Day 22 or 23, propionate and acetate mole percentages were 12 and 62%, respectively, in TSF-05A and 7 and 66%, respectively, in TSF-05B. TAN-25 had 230 mg/L and 17% mole percentage for propionate and 540 mg/L and 49% mole

Table A-8. Electron donor data for the August 16, 2004, whey powder injection in TSF-05.

Well	Time Elapsed After Injection (Days)	COD (mg/L)	Lactose (mg/L) Molar%	Propionate (mg/L) Molar%	Acetate (mg/L) Molar%	Butyrate (mg/L) Molar%	Isobutyrate (mg/L) Molar%	Isovalerate (mg/L) Molar%	Valerate (mg/L) Molar%	Hexonoate (mg/L) Molar%
TSF-05A	2	17,700	14,800	59	420	0[b]	0[b]	0[b]	0	0
			84%	2%	14%	0%	0%	0%	0%	0%[b]
TSF-05A	4	6,300	2,200	331.2	1,000	33	0[b]	0[b]	0	0
			22%	16%	60%	1%	0%	0%	0%	0%
TSF-05A	8	2,900	0[c]	880	1,800	784	0[b]	0[b]	0	0
			0%	23%	59%	17%	0%	0%	0%	0%
TSF-05A	23	441	0[c]	44	186	50	25	28	7	0
			3%	12%	62%	11%	6%	5%	1%	0%
TSF-05A	36	66	0	0[b]	16	0[b]	0[b]	16	0[b]	0
			0%	0%	49%	0%	0%	29%	0%	0%
TSF-05B	2	20,000	13,800	80	780	0[b]	0[b]	0[b]	0	0
			74%	2%	24%	0%	0%	0%	0%	0%
TSF-05B	4	16,300	9,400	280	1,245	107	0[b]	0[b]	0	0
			51%	7%	39%	2%	0%	0%	0%	0%
TSF-05B	9	8,500	567	980	1,900	2,300	11	33	23	0
			2%	19%	44%	36%	0%	0%[a]	0%[a]	0%
TSF-05B	23	1,900	0[c]	280	630	470	41	38	23	8
			0%	7%	66%	14%	4%	1%	5%	3%
TSF-05B	37	322	0	22	170	54	14	0[b]	20	17
			0%	7%	66%	14%	4%	0%	5%	3%
TAN-25	2	22,000	15,600	120	813	0[b]	0[b]	0[b]	0	0
			75%	3%	23%	0%	0%	0%	0%	0%
TAN-25	4	12,700	3,200	240	1,600	105	9	20	0	0
			23%	8%	65%	3%	0%[a]	0%[a]	0%	0%

jTable A-8. (continued).

Well	Time Elapsed After Injection (Days)	COD (mg/L)	Lactose (mg/L) Molar%	Propionate (mg/L) Molar%	Acetate (mg/L) Molar%	Butyrate (mg/L) Molar%	Isobutyrate (mg/L) Molar%	Isovalerate (mg/L) Molar%	Valerate (mg/L) Molar%	Hexonoate (mg/L) Molar%
TAN-25	9	6,900	0[c]	1,900	5,400	3,700	7	21	0	0
			0%	16%	57%	26%	0%[a]	0%[a]	0%	0%
TAN-25	23	1,700	0[c]	230	540	356	95	86	20	9
			1%	17%	49%	22%	6%	4%	1%	0%[a]
TAN-25	37	211	0	0[b]	10	0[b]	2	76	0	0
			0%	N/A	17%	N/A	2%	74%	0%	0%
TAN-31	2	12,000	9,800	81	310	0[b]	0[b]	0[b]	0	0
			82%	3%	15%	0%	0%	0%	0%	0%
TAN-31	4	7,900	3,500	135	450	3	0[b]	12	0	0
			51%	9%	38%	c0%	0%	1%	0%	0%
TAN-31	8	4,400	0[c]	940	1,250	346	0[c]	0[b]	0	0
			0%	34%	56%	10%	0%	0%	0%	0%
TAN-31	23	612	0	110	133	178	27	31	10	0
			0%	23%	35%	31%	5%	5%	1%	0%
TAN-31	37	110	0	8	21	4	2	0[b]	0[b]	0
			0%	18%	61%	8%	5%	0%	0%	0%
TAN-1859	8	880	0	260	390	32	0[b]	0[b]	0	0
			0%	33%	63%	4%	0%	0%	0%	0%
TAN-1859	37	31	0	0c	8	0[b]	0	0	0	0
			0%	0%	61%	0%	0%	0%	0%	0%

a. Although there are VFAs present when the molar percentage was calculated, the percent of the VFA was so small that 0% was recorded.
b. Value reported as <5 mg/L, which means that VFA was detected but below the MDL. These values are therefore reported here as 0 mg/L and molar percentages were calculated using one half the MDL.
c. Value reported as <100 mg/L, which means that lactose was detected but below the MDL. These values are therefore reported here as 0 mg/L and molar percentages were calculated using one half the MDL.

percentage for acetate. TAN-31 had 110 mg/L of propionate, 133 mg/L acetate, 178 mg/L butyrate, and <100 mg/L of other VFAs at the Day 22 or 23 sampling event. By Days 36–38, the electron donor had been depleted at all of the wells, with TSF-05A having 16 mg/L each of acetate and isovalerate, 22 mg/L propionate, 170 mg/L acetate, 54 mg/L butyrate, 14 mg/L isobutyrate, 20 mg/L valerate, and 17 mg/L hexanoate. TAN-25 and TAN-31 had only low concentrations of acetate (10 and 8 mg/L, respectively).

The second whey powder injection occurred on October 11, 2004. For the second and third whey powder injections, a Day 15 sampling event was added to the high frequency sampling. COD concentrations at TSF-05A (17,964 mg/L), TSF-05B (21,168 mg/L), TAN-31 (15,390 mg/L), and TAN-1859 (2,049 mg/L) wells were higher following the second whey powder injection than COD concentrations after the first whey injection but were lower for TAN-25 (22,000 mg/L vs. 18,288 mg/L) (Table A-9). COD concentrations at TAN-1859 were much higher (2,049 mg/L) following the second whey injection than observed at this well after the lactate injections and the first whey powder injection.

High concentrations of lactose were observed at TSF-05A (21,414 mg/L), TSF-05B (17,337 mg/L), TAN-25 (11,172 mg/L), and TAN-31 (8,634 mg/L) the day after the whey powder injection (Table A-9). By the Day 4 sampling event, lactose concentrations had significantly declined at TSF-05A (3,374 mg/L), TSF-05B (10,105 mg/L), TAN-25 (3,913 mg/L), and TAN-31 (5,051 mg/L). By the Days 8–10 sampling event, lactose concentrations were depleted at all monitoring locations except for TSF-05B (~800 mg/L). By Day 15, lactose was gone at all of the monitoring locations but the conversion of lactose to acetate and propionate, as well as other VFAs, was evident. TAN-25 had 560 mg/L propionate, 780 mg/L acetate, and 281 mg/L butyrate, while TAN-31 had 623 mg/L propionate, 670 mg/L acetate, and 183 mg/L butyrate. TSF-05A and TSF-05B also had high concentrations of VFAs at the Day 15 sampling event. TSF-05A had 360 mg/L propionate, 583 mg/L acetate, and 190 mg/L butyrate, while TSF-05B had 699 mg/L propionate, 1,174 mg/L acetate, and 587 mg/L butyrate. By Day 22 or 23, there was no remaining lactose at all of the AED wells, and major VFA (i.e., propionate, acetate, and butyrate) concentrations were depleted at all of the wells, including TSF-05A with 34, 113, and 11 mg/L, respectively, and TSF-05B with 57, 120, and 31 mg/L, respectively. Propionate, acetate, and butyrate were also diminished at TAN-25 with 29, 47, and 0 mg/L, respectively, and TAN-31 with 53, 31, and 11 mg/L, respectively, by Day 22 or 23. There were no remaining electron donor and daughter products at TSF-05A and TAN-25 by the Day 36–38 sampling event. TSF-05B had low concentrations of acetate (56 mg/L) and propionate (7 mg/L), while TAN-31 only had minimal concentrations of acetate (18 mg/L).

The third whey powder injection occurred on January 10, 2004. The Day 2 COD concentrations at TSF-05A (19,476 mg/L), TSF-05B (23,508 mg/L), and TAN-1859 (4,032 mg/L) were higher following the third whey powder injection than COD concentrations observed directly after the previous two whey powder injections (Table A-10). TAN-1859 was sampled at the higher AED sampling frequency (sampling on Day 2, 4, 15, and 22 or 23 added) during the third whey powder injection cycle. COD concentration at TAN-25 and TAN-31 (19,458 mg/L and 12,636 mg/L, respectively), however, were lower.

Table A-9. Electron donor data for the October 11, 2004, whey powder injection in TSF-05.

Well	Time Elapsed After Injection (Days)	COD (mg/L)	Lactose (mg/L) Molar%	Propionate (mg/L) Molar%	Acetate (mg/L) Molar%	Butyrate (mg/L) Molar%	Isobutyrate (mg/L) Molar%	Isovalerate (mg/L) Molar%	Valerate (mg/L) Molar%	Hexonoate (mg/L) Molar%
TSF-05A	2	17,964	21,414	148	723	23	7	11	0	0
			82%	3%	16%	0%	0%	2%	0%	0%[b]
TSF-05A	4	7,731	3,374	618	1,396	245	11	19	0	0
			51%	19%	52%	6%	0%[b]	0%[a]	0%	0%
TSF-05A	8	3,303	0[c]	678	1,245	414	14	27	8	0
			0%	26%	59%	13%	0%[b]	1%	0%[a]	0%
TSF-05A	15	1,395	0[c]	360	583	190	52	64	23	11
			1%	26%	53%	12%	0%[b]	3%	0%[a]	0%
TSF-05A	23	321	0	34	113	11	14	39	6	0
			0%	15%	61%	4%	5%	13%	2%	0%
TSF-05A	36	42	0	0	0	0	0	0	0	0
			0%	0%	0%	0%	0%	0%	0%	0%
TSF-05B	2	21,168	17,337	191	918	46	7	9	0	0
			73%	4%	22%	1%	0%	0%	0%	0%
TSF-05B	4	13,860	10,105	564	1,911	557	15	23	0	0
			39%	10%	42%	8%	0%[b]	0%[a]	0%	0%
TSF-05B	9	6,822	824	1,134	2,459	1,538	20	31	16	0
			3%	20%	53%	23%	0%[b]	0%[a]	0%	0%
TSF-05B	15	2,217	0[c]	699	1,174	587	64	80	38	14
			0%	25%	52%	18%	2%	2%	1%	0%
TSF-05B	23	744	0	120	248	57	31	58	14	0
			0%	22%	55%	9%	5%	8%	2%	0%

Table A-9. (continued).

Well	Time Elapsed After Injection (Days)	COD (mg/L)	Lactose (mg/L) Molar%	Propionate (mg/L) Molar%	Acetate (mg/L) Molar%	Butyrate (mg/L) Molar%	Isobutyrate (mg/L) Molar%	Isovalerate (mg/L) Molar%	Valerate (mg/L) Molar%	Hexonoate (mg/L) Molar%
TSF-05B	37	125	0	7	56	0	0	0	0	0
			0%	9%	86%	0%	0%	0%	0%	0%
TAN-25	2	18,288	11,172	193	1,110	33	14	21	0	0
			75%	5%	34%	1%	0%[a]	0%[a]	0%	0%
TAN-25	4	8,829	3,913	641	2,035	503	20	28	0	0
			23%	14%	57%	9%	0%[a]	0%[a]	0%	0%
TAN-25	9	4,788	0[c]	1,854	3,628	1,446	46	104	28	16
			0%	24%	58%	16%	1%	1%	0%[a]	0%[a]
TAN-25	15	2,631	0	560	780	281	95	110	36	18
			0%	29%	49%	12%	4%	4%	1%	1%
TAN-25	23	522	0	29	47	0	20	55	0	0
			0%	20%	40%	0%	12%	28%	0%	0%
TAN-25	37	106	0	0[b]	0	0	0[b]	0[b]	0	0
			0%	0%	0%	0%	0%	0%	0%	0%
TAN-31	2	15,390	8,637	158	489	13	11	14	0	0
			82%	6%	23%	0%	0%[a]	0%[a]	0%	0%
TAN-31	4	7,749	5,051	1,100	1,558	341	22	30	0	0
			51%	15%	23%	6%	0%[a]	0%[a]	0%	0%
TAN-31	8	3,402	0[c]	1,293	1,696	597	21	42	19	0
			0%	33%	53%	13%	0%[a]	1%	0%[a]	0%
TAN-31	15	1,533	0	623	670	183	35	71	28	10
			0%	36%	48%	9%	0%[a]	3%	1%	0%[a]
TAN-31	23	263	0	53	31	11	6	23	0	0
			0%	36%	48%	9%	2%	3%	1%	0%

Table A-9. (continued).

Well	Time Elapsed After Injection (Days)	COD (mg/L)	Lactose (mg/L) Molar%	Propionate (mg/L) Molar%	Acetate (mg/L) Molar%	Butyrate (mg/L) Molar%	Isobutyrate (mg/L) Molar%	Isovalerate (mg/L) Molar%	Valerate (mg/L) Molar%	Hexonoate (mg/L) Molar%
TAN-31	37	76	0	0	18	0	0	0	0	0
			0%	0%	78%	0%	0%	0%	0%	0%
TAN-1859	8	2,049	0	987	1,133	112	27	49	19	0
			0%	39%	55%	4%	0%	1%	1%	0%
TAN-1859	37	178	0	43	32.2	0[b]	0	0[b]	0	0
			0%	50%	46%	0%	0%	0%	0%	0%

a. Although there are VFAs present when the molar percentage was calculated, the percent of the VFA was so small that 0% was recorded.
b. Value reported as <5 mg/L, which means that VFA was detected but below the MDL. These values are therefore reported here as 0 mg/L and molar percentages were calculated using one half the MDL.
c. Value reported as <100 mg/L, which means that lactose was detected but below the MDL. These values are therefore reported here as 0 mg/L and molar percentages were calculated using one half the MDL.

Table A-10. Electron donor data for the January 10, 2005, whey powder injection in TSF-05.

Well	Time Elapsed After Injection (Days)	COD (mg/L)	Lactose (mg/L) Molar%	Propionate (mg/L) Molar%	Acetate (mg/L) Molar%	Butyrate (mg/L) Molar%	Isobutyrate (mg/L) Molar%	Isovalerate (mg/L) Molar%	Valerate (mg/L) Molar%	Hexonoate (mg/L) Molar%
TSF-05A	2	19,476	11,197	86	374	24	5	8	0	0
			82%	3%	15%	1%	0%[a]	0%[a]	0%	0%
TSF-05A	4	9,972	4,835	557	1,326	684	10	17	0[b]	0
			27%	15%	43%	15%	0%[a]	0%[a]	0%[a]	0%
TSF-05A	8	4,896	0[c]	825	1,475	1,054	18	36	14	0
			0%	23%	51%	25%	0%[a]	1%	0%[a]	0%
TSF-05A	15	2,151	0[c]	386	574	383	44	61	27	11
			0%	15%	47%	21%	2%	3%	1%	0%[a]
TSF-05A	23	687	0	64	119	30	30	36	10	6
			0%	22%	50%	9%	8%	9%	2%	1%
TSF-05A	36	101	0	0[b]	0	0[b]	0[b]	0[b]	0	0
			0%	0%	0%	0%	0%	0%	0%	0%
TSF-05B	2	23,508	11,457	114	419	41	5	9	0	0
			73%	4%	17%	1%	0%[a]	0%[a]	0%	0%
TSF-05B	4	15,552	4,991	318	1,075	676	8	14	0[b]	0
			39%	10%	40%	17%	0%[a]	0%[a]	0%	0%
TSF-05B	9	6,426	0[c]	817	1,574	1,597	16	27	14	5
			3%	20%	47%	32%	0%[a]	0%[a]	0%[a]	0%
TSF-05B	15	3,308	0	526	863	729	33	50	30	10
			0%	23%	46%	27%	0%[a]	1%	2%	1%
TSF-05B	23	1118	0	128	210	94	37	46	15	8
			0%	23%	48%	14%	6%	6%	2%	1%
TSF-05B	37	312	0	32	210	0[b]	5	12	0	0
			0%	18%	75%	0%	0%[a]	2%	0%	0%
TAN-25	2	19,458	11,135	156	828	88	14	26	0	0
			65%	4%	28%	2%	0%	1%	0%	0%

Table A-10. (continued).

Well	Time Elapsed After Injection (Days)	COD (mg/L)	Lactose (mg/L) Molar%	Propionate (mg/L) Molar%	Acetate (mg/L) Molar%	Butyrate (mg/L) Molar%	Isobutyrate (mg/L) Molar%	Isovalerate (mg/L) Molar%	Valerate (mg/L) Molar%	Hexonoate (mg/L) Molar%
TAN-25	4	9,432	2,164	719	1,931	1,333	22	34	6	0
			10%	15%	50%	24%	0%[a]	1%	0%[a]	0%
TAN-25	9	5,688	0[c]	1,004	1,932	1,449	50	68	25	11
			0%	21%	50%	26%	1%	1%	0%[a]	0%[a]
TAN-25	15	3,564	0	601	741	621	101	102	41	20
			0%	27%	41%	23%	4%	3%	1%	1%
TAN-25	23	1059	0	99	81	19	59	81	17	8
			0%	29%	30%	5%	14%	17%	4%	1%
TAN-25	37	148	0	0[b]	0	0[b]	0[b]	0[b]	0	0
			0%	0%	0%	0%	0%	0%	0%	0%
TAN-31	2	12,636	8,200	118	497	42	12	15	0	0
			69%	5%	24%	1%	0%[a]	0%[a]	0%	0%
TAN-31	4	6,660	2,001	664	1,095	535	15	21	0[b]	0
			15%	23%	46%	15%	0%[a]	0%[a]	0%	0%
TAN-31	8	4,221	0[c]	883	1,193	535	20	39	15	0
			0%	31%	52%	16%	0%[a]	1%	1%	0%
TAN-31	15	2,331	0	509	521	234	31	58	26	10
			0%	35%	45%	14%	0%[a]	2%	3%	1%
TAN-31	23	594	0	85	26	6	12	27	6	0
			0%	54%	20%	3%	7%	12%	3%	0%
TAN-31	37	138	0	0[b]	0	0	0	0[b]	0	0
			0%	0%	0%	0%	0%	0%	0%	0%
TAN-1859	2	4,032	2,506	82	261	5	0[b]	6	0	0
			56%	9%	34%	0%	0%[a]	0%[a]	0%	0%
TAN-1859	4	1,971	0[c]	618	760	26	6	9	0	0
			0%	39%	59%	0%	0%[a]	0%[a]	0%	0%

Table A-10. (continued).

Well	Time Elapsed After Injection (Days)	COD (mg/L)	Lactose (mg/L) Molar%	Propionate (mg/L) Molar%	Acetate (mg/L) Molar%	Butyrate (mg/L) Molar%	Isobutyrate (mg/L) Molar%	Isovalerate (mg/L) Molar%	Valerate (mg/L) Molar%	Hexonoate (mg/L) Molar%
TAN-1859	8	705	0	282	306	28	17	30	12	0
			0%	39%	52%	1%	2%	3%	1%	0%
TAN-1859	15	160	0	13	25	5	0[b]	5	0	0
			0%	0%	83%	3%	4%	7%	0%	0%
TAN-1859	23	60	0	0	0	0	0	0	0	0
			0%	0%	0%	0%	0%	0%	0%	0%
TAN-1859	37	63	0	0	0	0	0	0	0	0
			0%	0%	0%	0%	0%	0%	0%	0%

a. Although there are VFAs present when the molar percentage was calculated, the percent of the VFA was so small that 0% was recorded.
b. Value reported as <5 mg/L, which means that VFA was detected but below the MDL. These values are therefore reported here as 0 mg/L and molar percentages were calculated using one half the MDL.
c. Value reported as <100 mg/L, which means that lactose was detected but below the MDL. These values are therefore reported here as 0 mg/L and molar percentages were calculated using one half the MDL.

In addition, high concentrations of lactose were observed at TSF-05A (11,977 mg/L), TSF-05B (11,457 mg/L), TAN-25 (11,135 mg/L), and TAN-31 (8,200 mg/L) the day after the whey powder injection (Table A-10). Lactose concentrations at TAN-1859 were 2,506 mg/L the day after injection in TSF-05. By the Day 4 sampling event, lactose was depleted at TAN-1859 and concentrations had significantly declined at TSF-05A (4,835 mg/L), TSF-05B (4,991 mg/L), TAN-25 (2,164 mg/L), and TAN-31 (2,001 mg/L). By the Days 8–10 sampling event, lactose concentrations were depleted at all of the monitoring locations, with only trace amounts (50 mg/L) remaining in TSF-05B and TAN-25. By Day 15, lactose was gone at all of the monitoring locations, but the conversion of lactose to butyrate, acetate and propionate as well as other VFAs was evident. TAN-25 had 601 mg/L propionate, 741 mg/L acetate, and 621 mg/L butyrate, while TAN-31 had 509 mg/L propionate, 521 mg/L acetate, and 234 mg/L butyrate. TSF-05A and TSF-05B also had high concentrations of VFAs at the Day 15 sampling event, with 386 and 526 mg/L, respectively, propionate; 574 and 863 mg/L, respectively, acetate; and 383 and 729 mg/L, respectively, butyrate. By Day 22 or 23, lactose was non-detect at all of the wells. At the Day 22 or 23 sampling, major VFA (propionate, acetate, and butyrate) concentrations were depleted at all of the wells, including TSF-05A with 64, 119, and 30 mg/L, respectively, and TSF-05B with 128, 210, and 94 mg/L, respectively. Propionate, acetate, and butyrate were also diminished at TAN-25 with 99, 81, and 29 mg/L, and TAN-31 with 85, 26, and 6 mg/L by Day 22 or 23. By Days 36–38, there were no remaining electron donors at all of the AED wells except for TSF-05B, (propionate 32 mg/L and acetate 210 mg/L).

At TAN-1859, lactose was gone by the Day 4 sampling event from 2,506 mg/L on Day 2 to <100 mg/L at Day 4. However, secondary VFAs were present at this well through the Day 15 sampling event, with 13 mg/L propionate, 25 mg/L acetate, and 5 mg/L each of butyrate and isovalerate at the Day 15 sampling event. There was no remaining electron donor from TAN-1859 by Day 22 or 23.

A-4.1.2.4 Degradation of Whey Powder Following Injections. The major electron donors observed in the AED wells during the sampling cycle following the whey powder injection were lactose, acetate, propionate, and butyrate. Minor products isobutyrate, isovalerate, valerate, and hexanoate were also observed at the AED wells. Formate was non-detect in every AED well during the AED optimization. The concentrations of electron donors and the molar percentages of each VFA in relation to the total VFA concentrations in the electron donor-impacted wells following the whey powder injections can be seen in Tables A-8, A-9, and A-10.

One week following the first whey injection (Days 8–10), propionate, acetate, and butyrate were the primary daughter products observed from lactose degradation, with high concentrations of each observed at TSF-05A (880, 1,800 and 784 mg/L, respectively), TSF-05B (980, 1,900, and 2,300 mg/L, respectively), TAN-25 (1,900, 5,400, and 3,700 mg/L, respectively), and TAN-31 (940, 1,250, and 346 mg/L, respectively). By the Day 22 or 23 sampling event, propionate, acetate, butyrate concentrations had declined at all of the sampling locations, but trace amounts (7–86 mg/L) of isobutyrate, isovalerate, valerate and hexanoate were detected. All of the electron donors were depleted by the Days 36–38 sampling event, with only minimal amounts remaining at any one of the wells. The following VFAs were observed: acetate and isovalerate at TSF-05A (16 and 16 mg/L, respectively); propionate (22 mg/L), acetate (170 mg/L), butyrate (54 mg/L), isobutyrate (14 mg/L), valerate (20 mg/L), and hexanoate (17 mg/L) at TSF-05B; isobutyrate (2 mg/L) and isovalerate (76 mg/L) at TAN-25; and propionate (8 mg/L), acetate (21 mg/L), butyrate (4 mg/L), and isobutyrate (2 mg/L) at TAN-31.

The electron donor area molar concentrations versus time for the AED wells and TAN-1859 throughout the AED optimization can be seen in Figures A-9 through A-13. These figures provide a visual representation of the amount of electron donor in molar concentrations with respect to one another. Following whey powder injections, high concentrations of lactose were converted primarily to propionate,

acetate, and butyrate by the Days 8–10 sampling event for all of the AED wells. By Days 36–38, other VFAs (i.e., isobutyrate, valerate, and isovalerate) persisted at low concentrations.

Electron donor was also distributed to TAN-1859, approximately 90 ft downgradient of the injection well (TSF-05), following the whey powder injection. Approximately 1 week (Days 8–10) after the injection, TAN-1859 had COD concentrations of 880 mg/L. By Days 8–10, no lactose was detected at TAN-1859 but propionate (260 mg/L), acetate (390 mg/L) and butyrate (32 mg/L) were detected. Only low concentrations of acetate (8 mg/L) were detected at TAN-1859 by the Days 36–38 sampling event.

The major electron donors observed in the AED wells during the sampling cycle following the second whey powder injection were similar to the first injection. These electron donors included lactose, acetate, propionate, and butyrate, as well as isobutyrate, isovalerate, valerate, and hexanoate (Table A-9). The concentrations of electron donors and the molar percentages of each VFA in relation to the total VFA concentrations in the electron donor-impacted wells can be seen in Table A-9. The week following the second injection (Days 8–10), propionate, acetate, and butyrate were the primary daughter products observed from lactose degradation, with high concentrations of each observed at TSF-05A (678, 1,245, and 414 mg/L, respectively), TSF-05B (1,134, 2,459, and 1,538 mg/L, respectively), TAN-25 (1,854, 3,628, and 1,446 mg/L, respectively), TAN-31 (1,293, 1,696, and 597 mg/L, respectively), and TAN-1859 (987, 1,133, and 112 mg/L, respectively). By the Day 15 sampling event, propionate, acetate, and butyrate concentrations had significantly declined, and trace amounts (10 to 110 mg/L) of isobutyrate, isovalerate, valerate, and hexanoate were detected at all of the wells. By the Days 36–38 sampling event, there was no electron donor at TSF-05A and TAN-25, and the only diminished electron donor present at the other AED wells included TSF-05B with 7 mg/L propionate and 56 mg/L acetate, TAN-31 with 18 mg/L acetate, and at TAN-1859, only propionate (43 mg/L) and acetate (32 mg/L) were still detected.

The major electron donors observed in the AED wells during the sampling cycle following the third whey powder injection were similar to the first two injections. The concentrations of electron donors and the molar percentages of each VFA in relation to the total VFA concentrations in the electron donor-impacted wells can be seen in Table A-10. The week following the third injection (Days 8–10), most of the AED wells showed peaks in propionate, acetate, and butyrate, with high concentrations of each observed at TSF-05A (825, 1,475, and 1,054 mg/L, respectively), TSF-05B (817, 1,574, and 1,597 mg/L, respectively), TAN-25 (1,004, 1,932, and 1,449 mg/L, respectively), and TAN-31 (883, 1,193, and 535 mg/L, respectively). However at TAN-1859, peak concentration of propionate (618 mg/L), acetate (760 mg/L) and butyrate (26 mg/L) were observed at Day 4 following the injection. By the Day 15 sampling event, propionate, acetate, and butyrate concentrations had significantly declined, and trace amounts (10 to 102 mg/L) of isobutyrate, isovalerate, valerate, and hexanoate were detected in all of the wells except TAN-1859, which showed decreased propionate, acetate, and butyrate concentrations at the Day 8–10 sampling event and very little (5 to 25 mg/L) of all VFAs by Day 15. By the Days 36–38 sampling event, there was no electron donor at TSF-05A, TAN-25, TAN-31, and TAN-1859, and only diminished electron donor was present at TSF-05B, with 32 mg/L propionate, 210 mg/L acetate, 5 mg/L isobutyrate, and 12 mg/L isovalerate.

A-4.1.3 Electron Donor Utilization

Evaluating the utilization rate of sodium lactate and whey powder is an important performance parameter in optimizing ISB operations at TAN. One goal of optimization is to minimize the number of times electron donor is injected. Utilization rates directly influence injection frequency. This section presents the data used to determine utilization rate following the two AED lactate injections compared with the three AED whey powder injections. The metrics used for calculating electron donor utilization within the residual source area were COD and lactate for the sodium lactate injections and COD and lactose for the whey powder injections. Past data suggest that COD is roughly equivalent to the sum of lactate or lactose and the fermentation products, and provides a good overall indicator for the presence

and longevity of the electron donor amendment. Concentration changes for each of these metrics following each injection were used to calculate a first order utilization rate coefficient. Figure A-14 illustrates the decline in COD concentrations at TAN-25 over an approximately 1-month period following each injection.

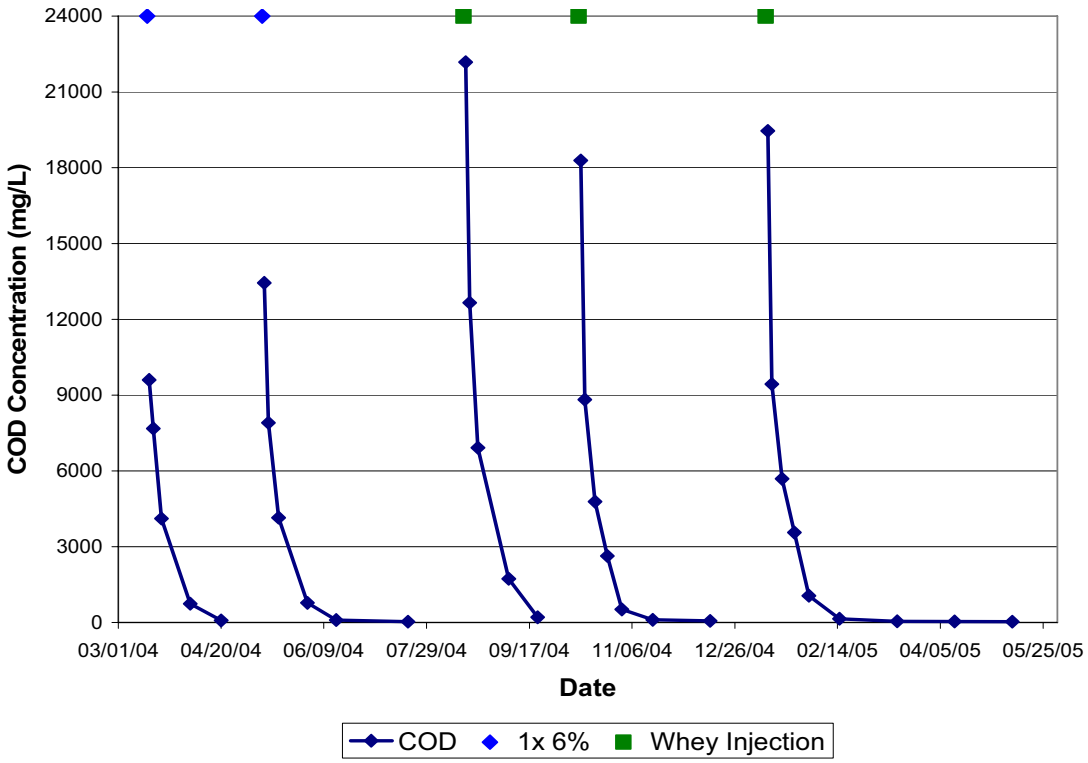

Figure A-14. Example of chemical oxygen demand drops at TAN-25 following injection events.

Electron donor utilization was evaluated by comparing the first order utilization rate coefficients following the two sodium lactate and three whey powder injections. COD utilization rate constants were calculated using the COD data from Day 2 through Days 36–38 sampling events following each AED injection. This provides a measure to establish the total longevity of the two amendment solutions following injection. The primary substrates lactate and lactose, however, were depleted more rapidly than the total COD, and so only data collected when the primary substrates were present were used. For lactate, utilization rate constants were calculated using the Day 2 through Day 22 or 23 sampling events, while lactose utilization rate (whey powder) constants were calculated using only Day 2 through Day 8–10 sampling events. The first order rate law for the consumption of reactant A (electron donor) is:

$$\frac{-d[A]}{dt} = k[A] \qquad \text{(A-12)}$$

where:

[A] = concentration of A

t = time

k = fraction of A consumed per unit of time (rate constant).

Integration of Equation A-12 with respect to time leads to:

$$[A]=[A]_0 e^{-kt} \quad \text{(A-13)}$$

where:

$[A]_0$ = initial concentration of A

[A] = concentration of A at time t.

The logarithmic form of Equation A-13 is:

$$\ln[A]=\ln[A]_0 - kt \quad . \quad \text{(A-14)}$$

According to Equation A-14, the first order rate constant, k, can be determined by plotting ln[A] versus time. The plot is a straight line, with the slope equal to "-*k*" and the intercept equal to "ln$[A]_0$". First order rate constants were calculated from the slope of ln[lactate or lactose] over time elapsed since each injection using data from TSF-05A, TSF-05B, TAN-25, and TAN-31 (Table A-11). Table A-12 presents the estimated first order utilization rate constants for COD after each injection.

Table A-11. First order lactate and lactose utilization rate constants.

Well	March 2004 1st Sodium Lactate Injection (day^{-1})	May 2004 2nd Sodium Lactate Injection (day^{-1})	August 2004 1st Whey Powder Injection (day^{-1})	October 2004 2nd Whey Powder Injection (day^{-1})	January 2005 3rd Whey Powder Injection (day^{-1})
TSF-05A	0.48	0.44	0.86	1.02	1.64
TSF-05B	0.47	0.48	0.48	0.45	0.80
TAN-25	0.29	0.27	0.87	0.72	0.57
TAN-31	0.29	0.35	1.64	1.37	1.33

Table A-12. First order chemical oxygen demand utilization rate constants.

Well	March 2004 1st Sodium Lactate Injection (day^{-1})	May 2004 2nd Sodium Lactate Injection (day^{-1})	August 2004 1st Whey Powder Injection (day^{-1})	October 2004 2nd Whey Powder Injection (day^{-1})	January 2005 3rd Whey Powder Injection (day^{-1})
TSF-05A	0.14	0.15	0.15	0.17	0.15
TSF-05B	0.10	0.11	0.12	0.15	0.12
TAN-25	0.14	0.09	0.12	0.14	0.13
TAN-31	0.15	0.17	0.13	0.15	0.13

The utilization rate constants calculated for lactate during the AED optimization using the high-frequency sampling were similar to those calculated using normal ISB sampling (Armstrong 2004, Macbeth 2005). After the two baseline lactate injections, the utilization rate constants ranged from 0.27 to 0.48 day^{-1} (Table A-11). TSF-05A and TSF-05B had the highest lactate utilization rate constants following the first lactate injection (0.48 and 0.47 day^{-1}, respectively), followed by TAN-25 and TAN-31 (each at 0.29 day^{-1}). Similar trends in lactate utilization rate constants were calculated following the second lactate injection. TSF-05B had the highest lactate rate constant (0.48 day^{-1}), then TSF-05A (0.44 day^{-1}), followed by TAN-31 (0.35 day^{-1}) and TAN-25 (0.27 day^{-1}). The utilization rate coefficients calculated following the two baseline lactate injections for a given well location were within 10% of each other. Utilization rate constants were not calculated at TAN-1859 after the 1X 6% sodium lactate injections into TSF-05 because electron donor was not present at high enough concentrations and did not persist long enough at this location to calculate a utilization rate constant.

After the whey powder injection, the utilization rate constants were calculated for the primary substrate lactose for each of the AED well locations. Overall, the utilization rate constants calculated for lactose were much higher than for lactate. For instance, well TSF-05B had a lactate utilization rate constant of 0.48 day^{-1} (average of two sodium lactate injections) and a lactose utilization rate constant of 0.58 day^{-1} (average of three whey injections). Likewise, TAN-31 was an average 0.32 day^{-1} for lactate and 1.45 day^{-1} average for lactose, TAN-25 was an average 0.28 day^{-1} for lactate and 0.72 day^{-1} for lactose, and at TSF-05A 0.46 day^{-1} following sodium lactate as compared to 1.17 day^{-1} following whey powder injections

The rate constants calculated using COD values represent a measure of the utilization rate for the combined electron donor within the system, including not only the primary substrate but also the fermentation by-products, providing a more general interpretation of electron donor utilization. The estimated rates are lower than the rates calculated for the primary substrates lactate and lactose because they inherently include the production and subsequent utilization of the secondary substrates (e.g., propionate and acetate), which are degraded at much slower rates than the primary substrates. The rate constants calculated using COD data for TSF-05A, TSF-05B, TAN-25 and TAN-31 ranged from 0.10 to 0.15 day^{-1} following the March 2004 sodium lactate injection and from 0.09 to 0.17 day^{-1} following the May 2004 sodium lactate injection (see Table A-12). After both injections, TAN-31 had the highest utilization rate constant while TSF-05B was generally the lowest. In general, the utilization rate constants calculated for COD during the AED optimization baseline are similar to utilization rate constants calculated during normal ISB operations (INEEL 2002, 2003b; Armstrong et al. 2004; Macbeth et al. 2005), with a range of 0.09 to 0.17 day^{-1} for COD.

The utilization rate constants calculated for COD following the whey injection ranged from 0.12 to 0.17 day^{-1}. These values were comparable when compared to those values observed following lactate injections (0.09 to 0.17 day^{-1}). This suggests that overall utilization of electron donors was generally comparable following whey powder injections versus sodium lactate. The longevity of whey powder using the TAN injection strategy should therefore be greater compared to lactate, given that it is injected at higher concentrations.

A-4.2 Geochemical Conditions

Geochemical conditions were monitored throughout the AED optimization. Monitoring included redox conditions (Section A-3.2.1), biological activity indicators (Section A-3.2.2), and water quality data (Section A-3.2.3).

A-4.2.1 Redox Conditions

In order for ARD of chloroethenes to proceed to completion at meaningful rates, the process must be energetically favorable. Complete transformation of TCE to ethene by ARD requires the absence of competing electron acceptors, which include oxygen, nitrate, ferric iron, manganese (IV), and sulfate (Figure A-15). ARD of TCE to cis-DCE requires redox conditions in the range of iron and sulfate reduction; however, complete dechlorination to ethene requires redox conditions that support methane production. At TAN, the most efficient ARD observed has been correlated to the onset of significant methanogenesis. Methanogenic conditions are indicated by the absence of sulfate (and other electron acceptors), the presence of ferrous iron, and the presence of methane. The locations that have achieved methanogenic redox conditions at TAN are those to which significant quantities of electron donor have been distributed.

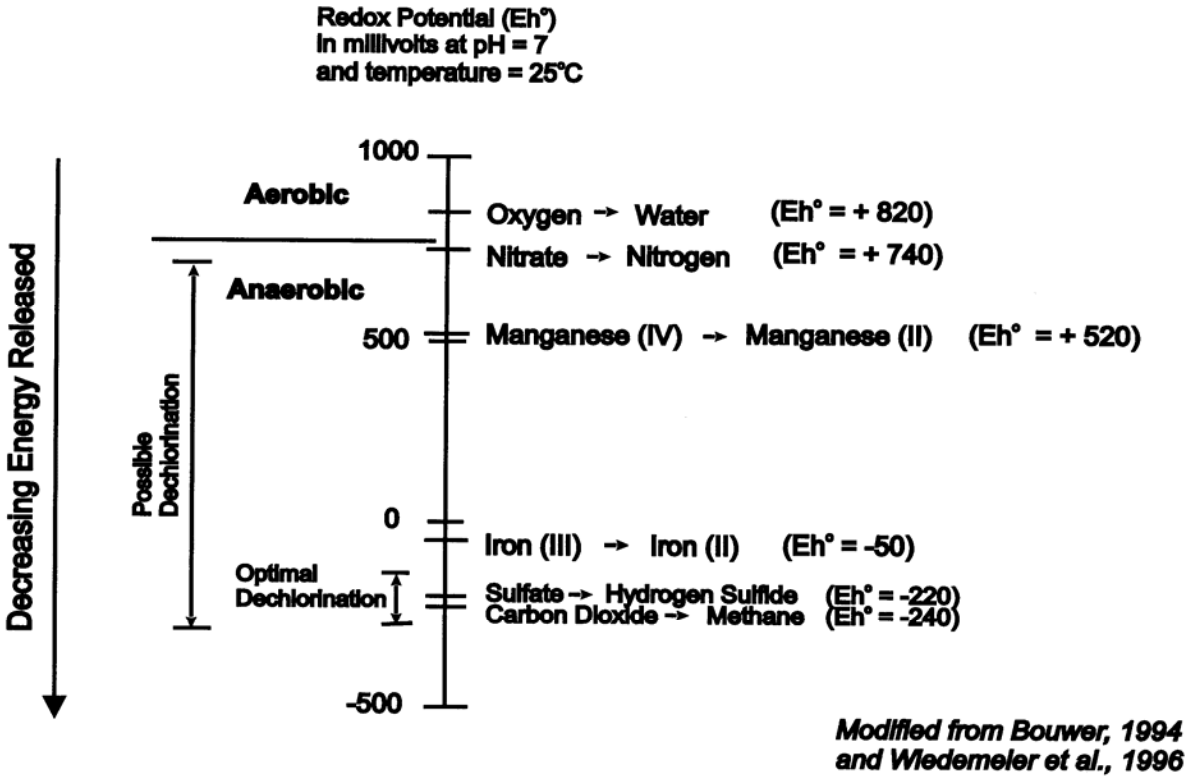

Figure A-15. Redox potential and relative available energy.

A-4.2.1.1 Baseline Sodium Lactate Redox Condition Results. Redox conditions at the AED well locations (TSF-05A, TSF-05B, TAN-25, TAN-31, and TAN-1859) following the baseline sodium lactate injections remained methanogenic. As demonstrated by elevated ferrous iron concentrations, complete reduction of sulfate, and significant methane production.

A-4.2.1.2 Whey Powder Redox Condition Results. Redox conditions at the AED well locations following the whey powder injections were similar to those observed following the baseline lactate injections with conditions remaining methanogenic. Following each whey powder injection, sulfate spiked on Days 2 or 4 to concentrations in the range of 7 to 14 mg/L at all AED well locations; however, sulfate concentrations decreased to 0 mg/L by Day 4 or Days 8–10 at all of the AED wells. Analysis of a 10% whey powder solution in the ISB field laboratory indicated that sulfate was present at approximately 130 mg/L in the injected whey powder solution that would be directly injected into the TAN aquifer.

Aside from the sulfate spikes directly following whey powder injections, sulfate concentrations remained at 0 mg/L at all AED wells, except for TSF-05A, which showed rebound in sulfate concentrations on Days 71–73 following the second baseline sodium lactate injection and on Day 120–121 following the third whey injection. Decreases in methane concentrations were observed on Day 4 following each whey injection, with concentrations rebounding by Day 15.

A-4.2.2 Methane Methods Comparison

Observations during sample collection following the first whey powder injection indicated that during the period when the groundwater was foamy (Days 2, 4, and 8–10), samples with no headspace were difficult to collect. This was cause for concern because significant degassing could occur during groundwater sample collection. To test this idea, E/E/M was collected using two different sample collection methods; the "new" method (described in Section A-2.3.3) and the "old" method of filling 40-mL vials.

Methane results for the old and new method at the AED wells are shown in Figures A-16 and A-17. The expected result was to see significantly higher methane concentrations using the new method on Days 2, 4, and 8–10 (when foamy water was present and collection of samples with no headspace was difficult) as compared to Days 22 and 36–38 (when the water was not foamy). However, the data comparing the two methods demonstrate trends that are similar, with decreases in concentrations on Day 2 and 4. In fact, the data show that the values obtained initially were closer between the two methods than samples collected at later points during an injection cycle. Therefore, significant degassing did not appear to occur to a greater extend during periods when foam was present using the old method compared with the new method. Overall, the new method captured more methane than the old method for all of the samples analyzed suggesting that it was a better method in general for collecting dissolved gas samples. However, the new method is not recommended for collection of future ISB E/E/M samples because a change in sampling method would not allow accurate comparison to historical concentrations.

A-4.2.3 Biological Activity Indicators

The biological activity indicators measured during the AED optimization include alkalinity and pH. When electron donor (both sodium lactate and whey powder) is degraded, alkalinity is expected to increase. Increases in alkalinity are a result of electron donor degradation reactions producing carbon dioxide, which dissociates in water to form carbonic acid and then further dissociates into bicarbonate and hydrogen. The production of bicarbonate and hydrogen during electron donor degradation are shown in degradation pathway equations in Section A-4.1.

Optimal microbial activity for ISB occurs under neutral pH conditions, typically in the range of 6 to 8. Primary substrate fermentation , such as lactate and lactose, following injection can result in production of high concentrations of volatile fatty acids over a relative short period of time resulting in decreases in pH, which can inhibit the productivity of the microbial community. However, high alkalinity in a groundwater system, consistently observed in TAN AED wells, can act as a buffer to reduce the magnitude of pH changes, the time during which pH remains low, and efficiently stabilize pH concentrations.

A-4.2.3.1 Baseline Sodium Lactate Results. Alkalinity continues to be high in all of the AED well locations, with concentrations ranging from 2,000 to 6,000 mg/L in these wells. No distinct changes in pH concentrations were observed following sodium lactate injections. Alkalinity and pH charts for all AED wells are shown in Figures A-18 to A-22.

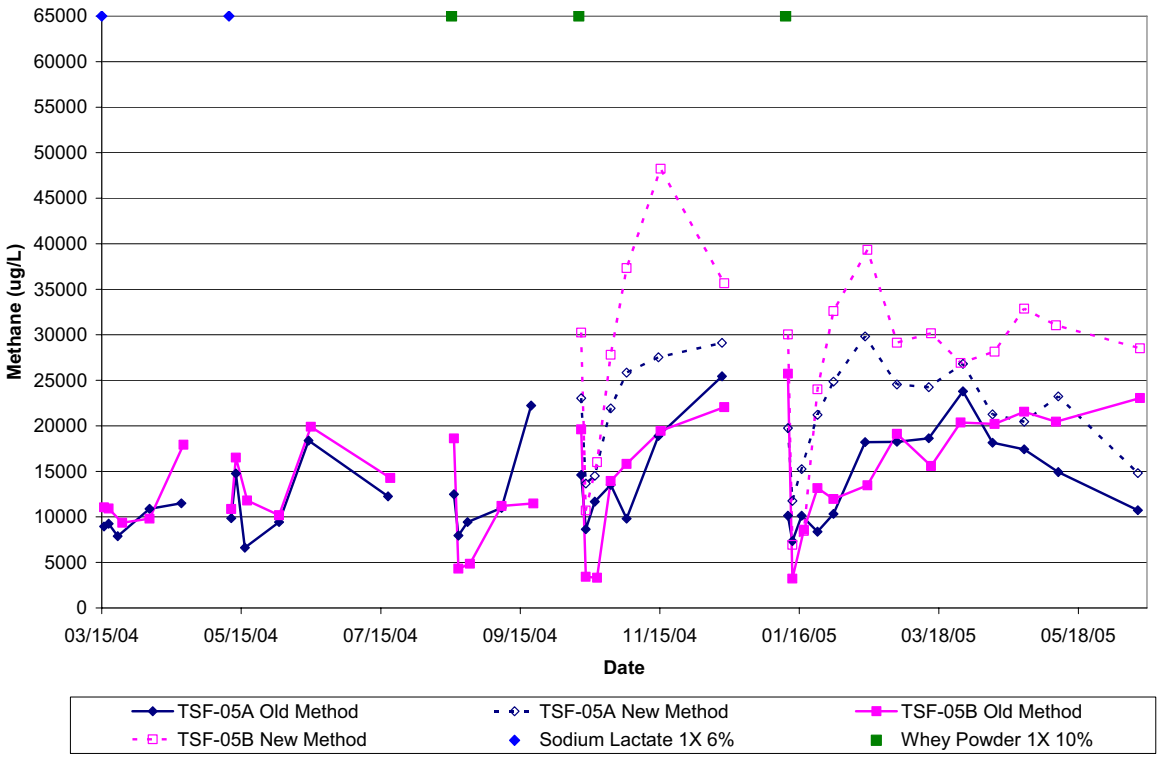

Figure A-16. Comparison of new and old methane results at TSF-05A and TSF-05B.

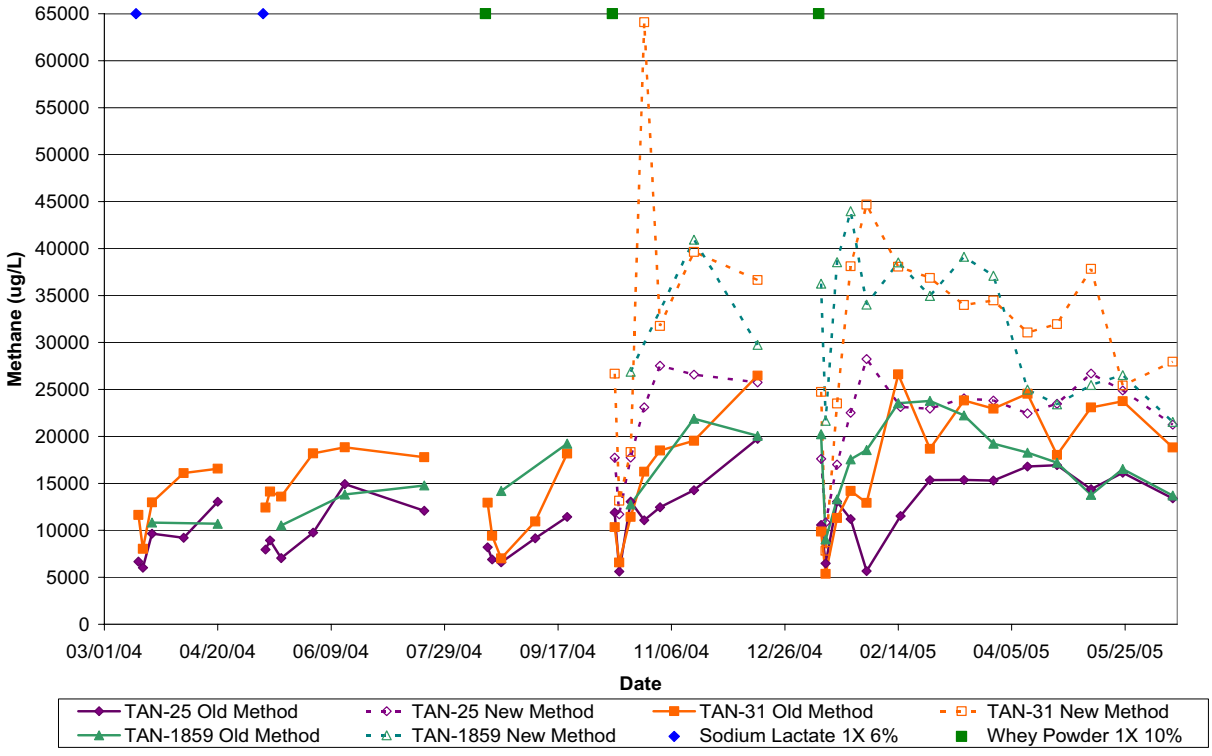

Figure A-17. Comparison of new and old methane results at TAN-25, TAN-31, and TAN-1859.

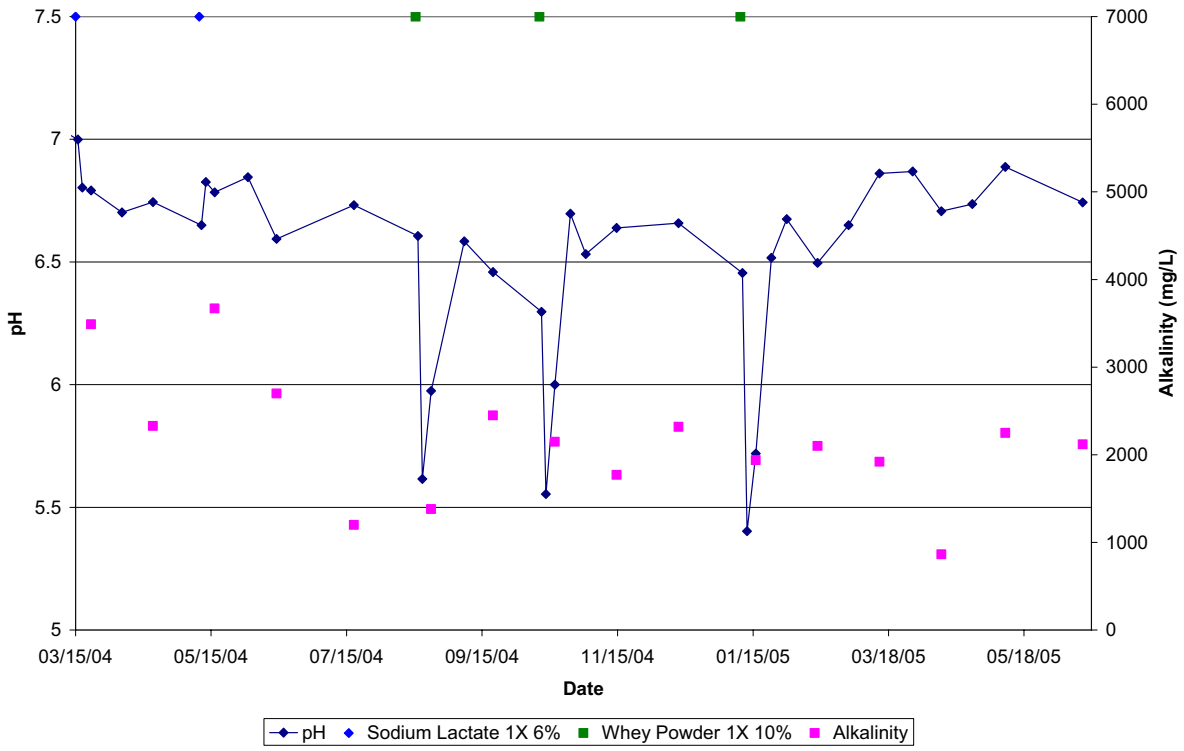

Figure A-18. Alkalinity and pH response at TSF-05A.

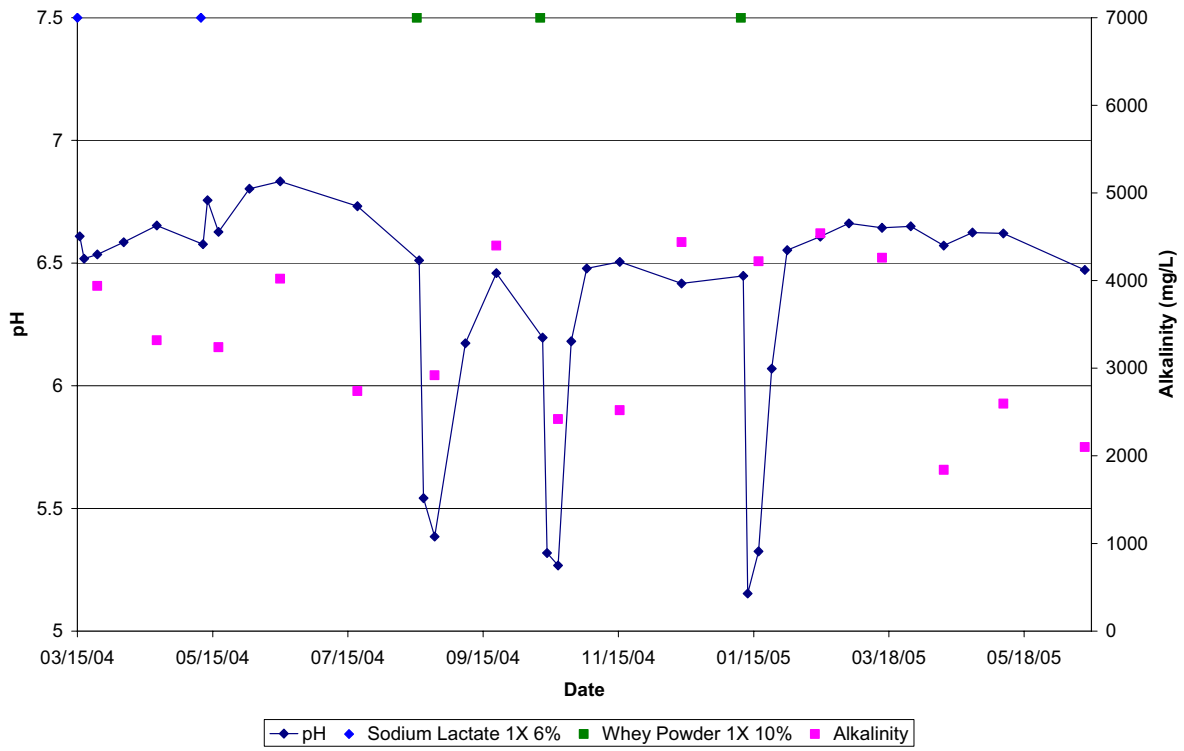

Figure A-19. Alkalinity and pH response at TSF-05B.

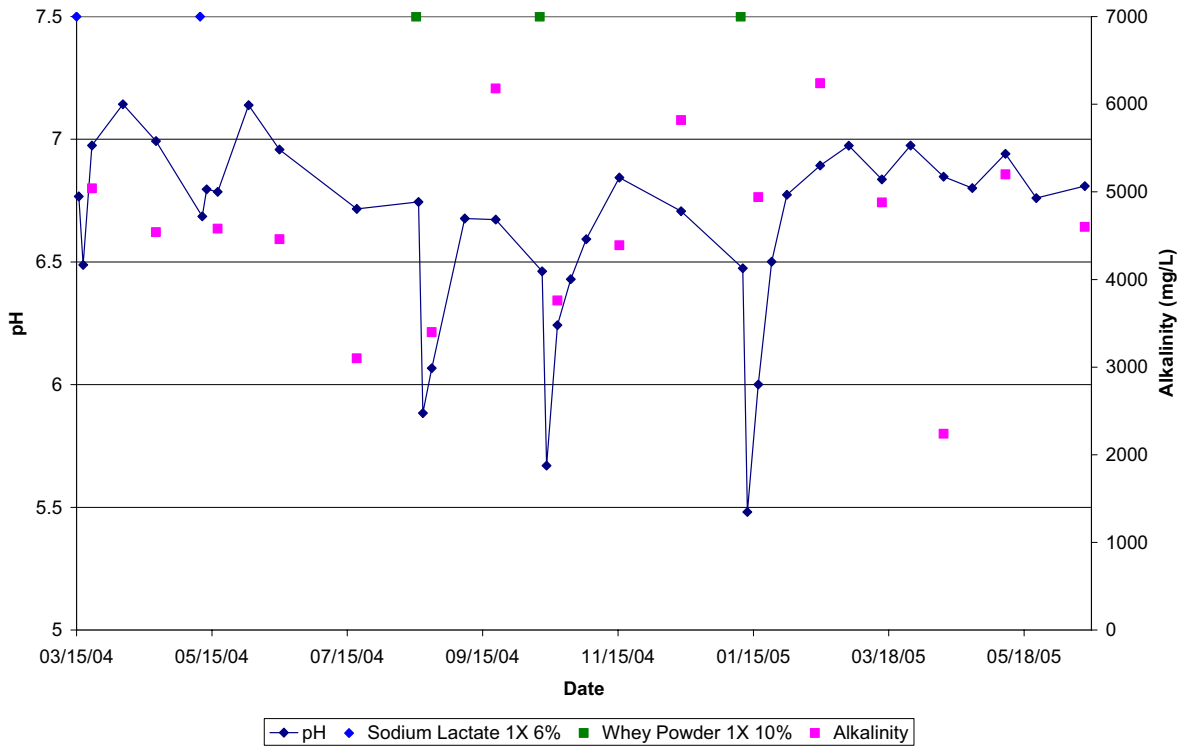

Figure A-20. Alkalinity and pH response at TAN-25.

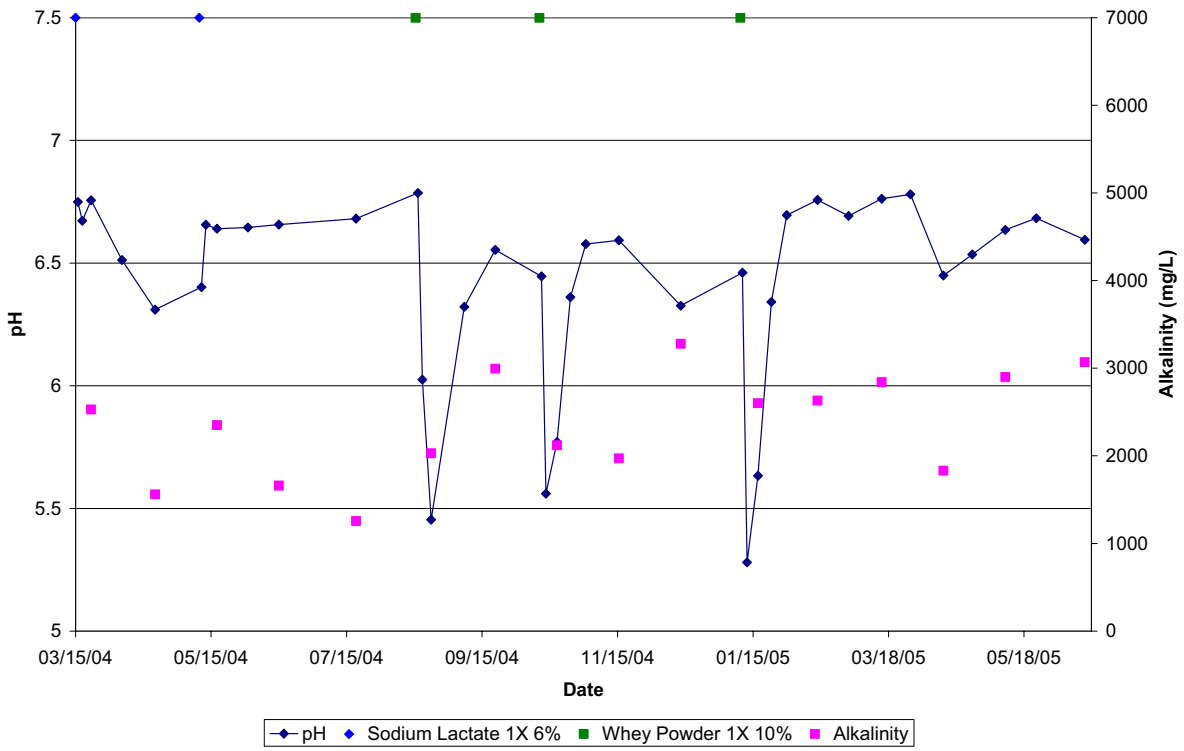

Figure A-21. Alkalinity and pH response at TAN-31.

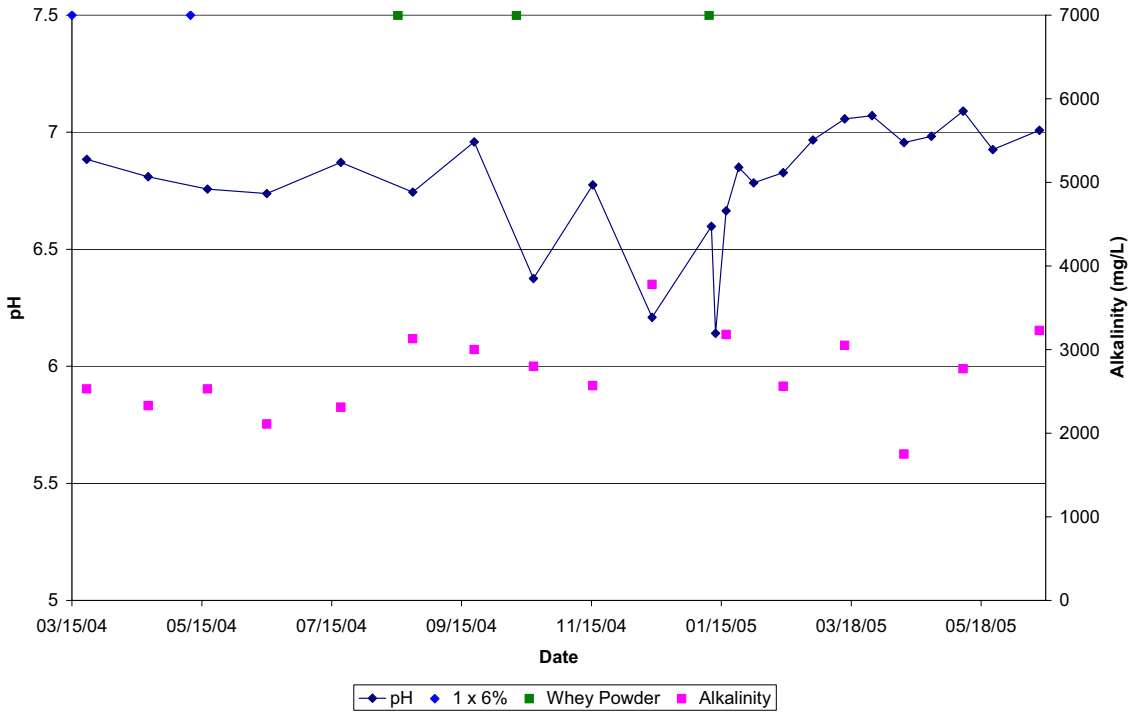

Figure A-22. Alkalinity and pH response at TAN-1859.

A-4.2.3.2 Whey Powder Results. Following the injection of whey powder, TSF-05A, TSF-05B, TAN-25, and TAN-31 showed a pH drop from an initial range of 6.5 to 7.0 to approximately 5.5 by Day 4 or Days 8–10 (Figures A-18 through A-21). This pH drop was observed following each of the three whey injections. The magnitude of the pH drop decreased as the distance from TSF-05 increased. For example, the pH at TAN-1859 dropped approximately 0.8 pH units from an initial value of 6.9 prior to injection of whey powder to 6.1 (Figure A-22). The pH rebounded in all of the AED wells by Day 22 or 23 to pre-injection levels.

A-4.2.4 Water Quality Data

During the AED optimization, multiparameter water quality instruments were used to collect water quality from a subset of the AED wells (TAN-25, TAN-31, and TAN-1859). Spikes in specific conductance occurred in response to sodium lactate and whey powder injections. Following each spike, specific conductance values gradually decreased until the next electron donor injection. The spikes following injections of whey powder, however, were much smaller than those following the lactate injections. This was expected since whey powder is not an ionic solution as is the sodium lactate solution. Temperature and ORP data were also used to assess the aquifer conditions for ARD in the source area. At TAN-31, conductivity increased by approximately 20 to 25 mS/cm in response to lactate injections into TSF-05 (Figure A-23). In addition, ORP increased approximately 200 mV at TAN-31 during all injections. Between injections, ORP gradually returned to a level of approximately -410 mV. Conductivity in TAN-1859 increased by approximately 6 to 7 mS/cm in response to sodium lactate and whey powder injections into TSF-05 (Figure A-24). The magnitude of conductivity spikes was similar at this location due to higher conductivity water being displaced from the vicinity of TSF-05. Changes in ORP were similar at TAN-1859 as those observed at TAN-31, with increases of 200 to 300 mV during injection events, while decreasing to a stable ORP of approximately -450 mV in the days following the injection.

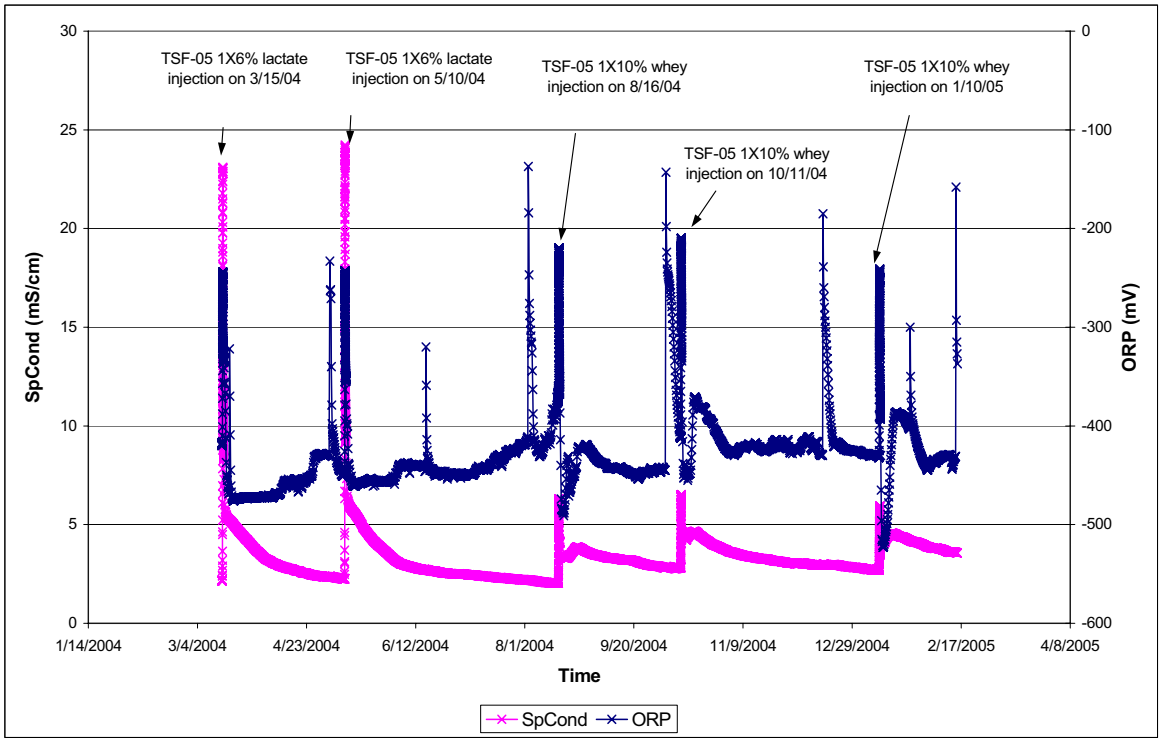

Figure A-23. Conductivity and oxidation reduction potential at TAN-31.

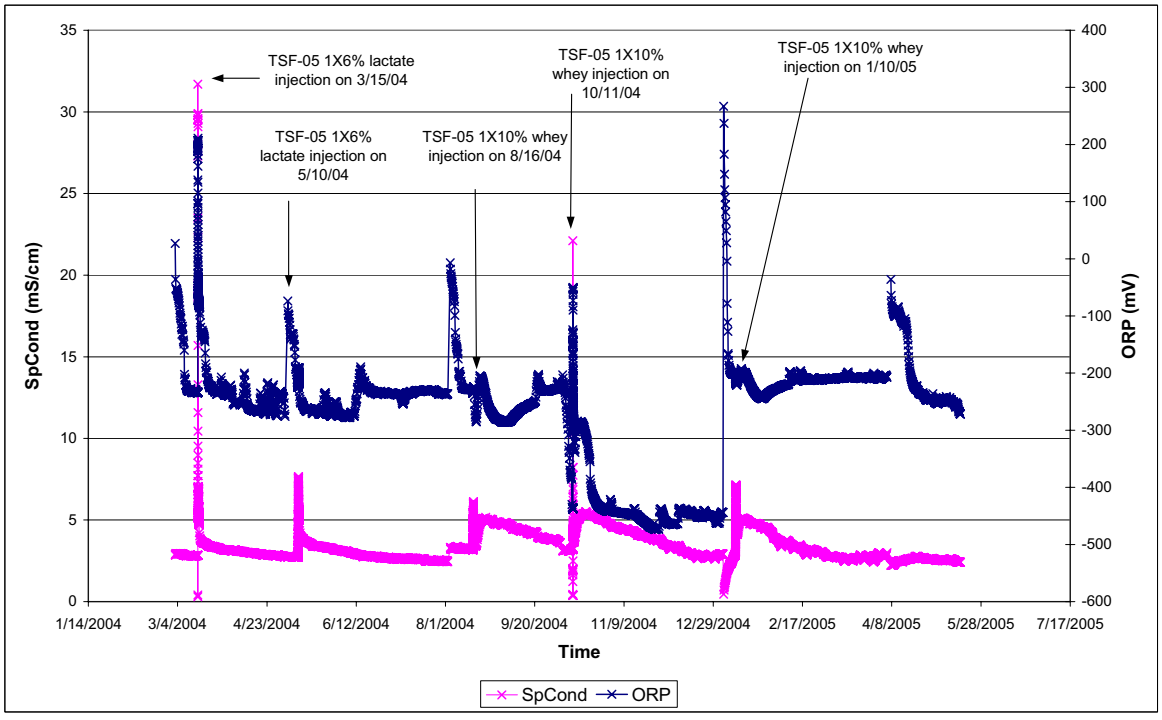

Figure A-24. Conductivity and oxidation reduction potential at TAN-1859.

Figure A-25 illustrates the peak observed water level mounding at TSF-05, TAN-25, TAN-31, and TAN-1859 for each electron donor injection during the AED optimization. Peaks were determined using data collected every 5 minutes from 6:00 a.m. through midnight on the day of injection. This figure also shows injection dates, volumes and rates, injection location, and electron donor type, which all affect the mounding response. Mounding in TSF-05 in early 1999 was approximately 2.5 ft and had increased to approximately 6 ft in 2000. For sodium lactate injections into TSF-05 during the AED optimization, mounding in TSF-05 has remained at approximately 5 to 6 ft (Figure A-25, a and b). Mounding following the whey injections into TSF-05 (Figure A-25, c, d, and e) also showed approximately 5 to 6 ft of mounding. Overall, peak mounding for all the wells appears to be consistent throughout the AED optimization, which is likely a result of the similar flowrates and volumes used for all electron donor injections. The consistency of these data suggests that biomass was not increasing in the biologically active zone such that flow paths were being affected beyond changes that have already taken place. The relative difference in peak mounding between TAN-25 and TAN-31 did not change during the AED optimization.

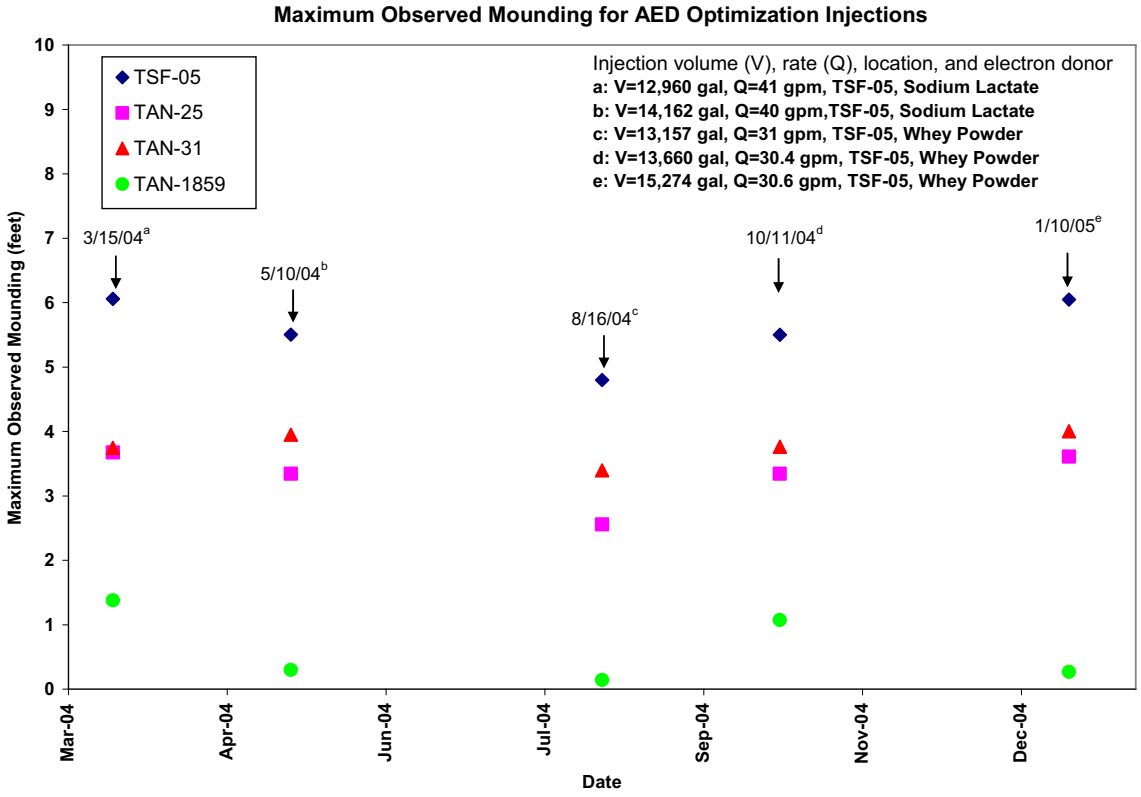

Figure A-25. Peak water level mounding for electron donor injections during the alternate electron donor optimization.

A-4.3 Anaerobic Reductive Dechlorination

During the AED optimization, the efficiency of the ARD reactions was assessed by examining changes in relative concentrations of TCE, cis-DCE, vinyl chloride (VC), and ethene. The increased sampling frequency conducted during the AED optimization allowed for a more thorough investigation of the response and fate of chlorinated ethenes following injections into TSF-05. ARD has been ongoing at all of the biologically active wells since 1999 and has continued throughout the AED optimization, as

evidenced by measurable ethene concentrations at all of the AED well locations. One trend was more noticeable as a result of increased sampling as part of the AED optimization: details regarding the dissolution of the residual source that occurs immediately following an injection. The magnitude of the contaminant concentrations, as TCE, increased dramatically following electron donor injections, and was more clearly defined with multiple sampling time points immediately following injections. The following sections describe the response of chloroethene and ethene concentrations at AED wells following sodium lactate and whey powder injections.

A-4.3.1 ARD and Enhanced Dissolution Results Following the Baseline Sodium Lactate Injections

As described in previous reports (INEEL 2002, 2003b; Armstrong et al. 2004; Macbeth et al. 2005), injection of sodium lactate resulted in an overall increase of chloroethene and ethene concentrations at all of the AED wells. Prior to increased sampling regimes, the historical metric for efficient and complete ARD within the source area was measured as increases in the concentration of ethene following the injection of electron donor. The kinetics of the degradation reactions were sufficiently fast that by the time the first sampling event took place following an injection (generally 1 week following the injection Days 8–10), much of the dissolved TCE was converted to ethene. In addition, the ambient dissolution that occurred over an injection cycle was also slower than the kinetics of the degradation reactions, and so parent compounds were rarely seen in the biologically active area. The samples collected at Days 2 and 4 following an injection provided sampling opportunities that ultimately revealed details regarding enhanced dissolution of the residual source, observed as increases in TCE, cis-DCE, and VC. The additional sampling illustrated significant spikes in TCE following the injections. This TCE was subsequently converted to cis-DCE, VC and ultimately to ethene.

Figures A-26 and A-27 illustrate the VOC mass response to the TSF-05 injections at the AED wells. At TSF-05A (Figure A-26), VOC and ethene concentrations were near 0 μg/L prior to the March 2004 sodium lactate injection but increased dramatically on Day 2 following the injection, with TCE at 120 μg/L, cis-DCE at 241 μg/L, and VC at 130 μg/L. By Days 8–10, concentrations of TCE had decreased and were nearly depleted, and cis-DCE was 41μg/L, VC was 23 μg/L. By the Days 36–38, TCE and cis-DCE were depleted, VC was 19 μg/L, and ethene was present at high concentrations (118 μg/L). This trend was replicated nearly perfectly at TSF-05A after the May 2004 sodium lactate injection except that ethene was even higher by Day 36–38 (231 μg/L).

At TSF-05B (Figure A-27), baseline ethene concentrations were approximately 100 μg/L before and after the sodium lactate injections. Following the March 2004 sodium lactate injection, high concentrations of VOCs as TCE (208 μg/L), cis-DCE (278 μg/L), and VC (101 μg/L) were observed on Day 2 of the sampling event. By Day 36–38, TCE was depleted with only ethene concentrations were high (88 μg/L), and cis-DCE (64 μg/L) present.

Following the May 2004 sodium lactate injection, TCE (208 μg/L), cis-DCE (278 μg/L), and VC (101 μg/L) concentrations again spiked at TSF-05B, reaching peak concentrations on Day 2. By the Days 71–73 sampling event (July 19–20, 2004), no chlorinated ethenes were observed at either TSF-05 well locations, and only ethene was present. The relative mass of ethene, however, was dramatically higher at TSF-05A (340 μg/L) at the Days 71–73 sampling event than at the Days 36–38 sampling event. Ethene concentrations at TSF-05B (91 μg/L) on the Days 71–73 sampling event, however, were slightly lower than the Days 36–38 sampling event.

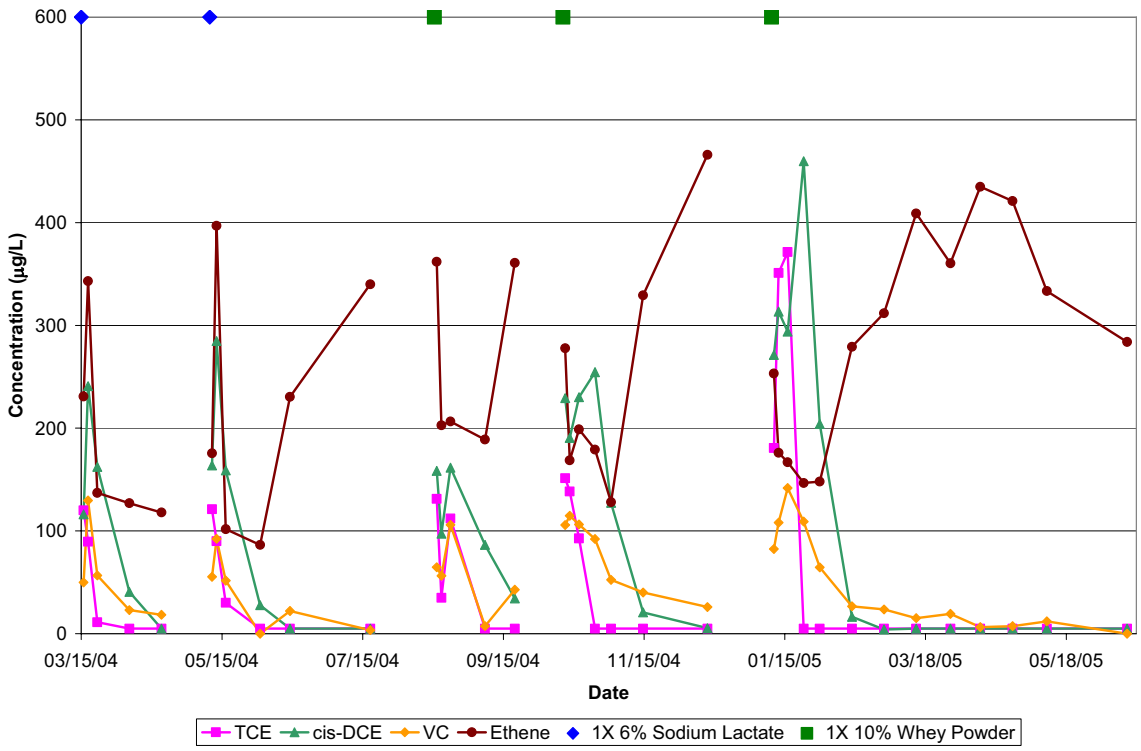

Figure A-26. Response of volatile organic compounds to sodium lactate and whey injections at TSF-05A.

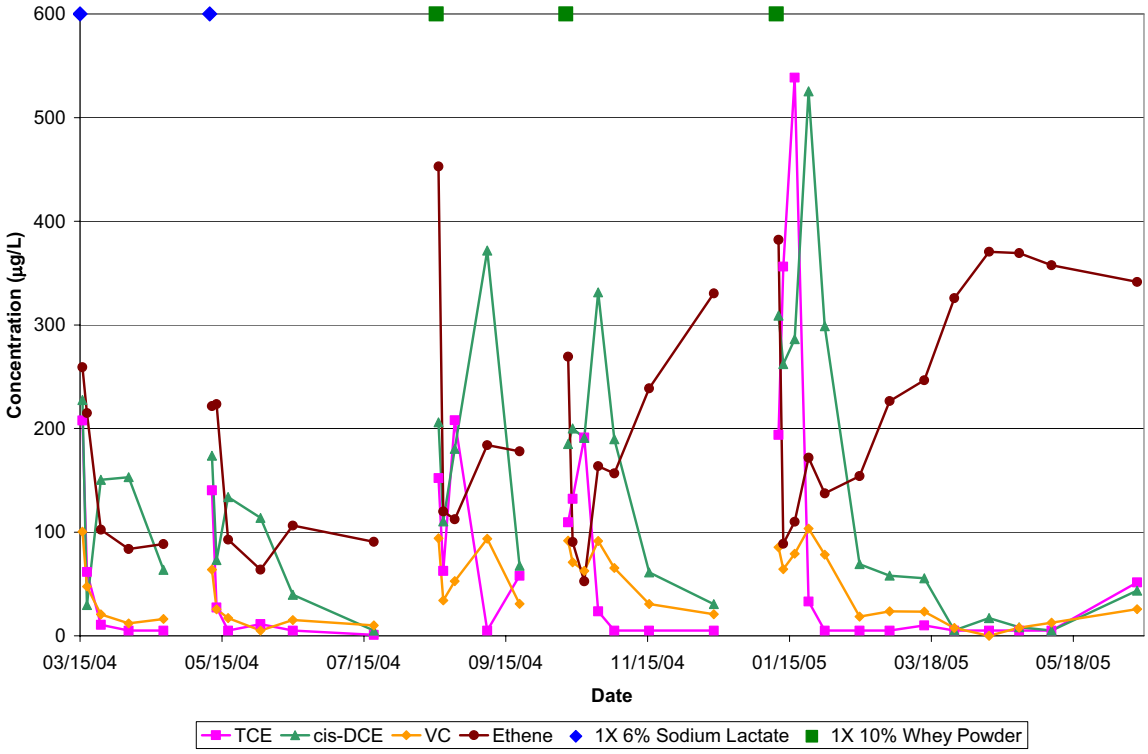

Figure A-27. Response of volatile organic compounds to sodium lactate and whey injections at TSF-05B.

Total chlorinated ethene concentrations at wells TAN-25 (Figure A-28) and TAN-31 (Figure A-29) also increased following the two lactate injections, although the magnitude of the spikes (<50 µg/L for TAN-25 and <20 µg/L for TAN-31) was much lower than in TSF-05A and TSF-05B. By the Days 36–38 sampling event, the chlorinated ethene concentrations had declined to near 0 µg/L. The same trend was observed following the May 2004 sodium lactate injection. The VOC response to sodium lactate injections at TAN-31 was observed primarily as spikes in ethene concentrations. As with contaminant concentrations at TSF-05, the peak VOC concentrations were observed on Day 4 and/or Days 8–10 at TAN-25 (Figure A-28), TAN-31 (Figure A-29), and TAN-1859 (Figure-30) following the three whey powder injections.

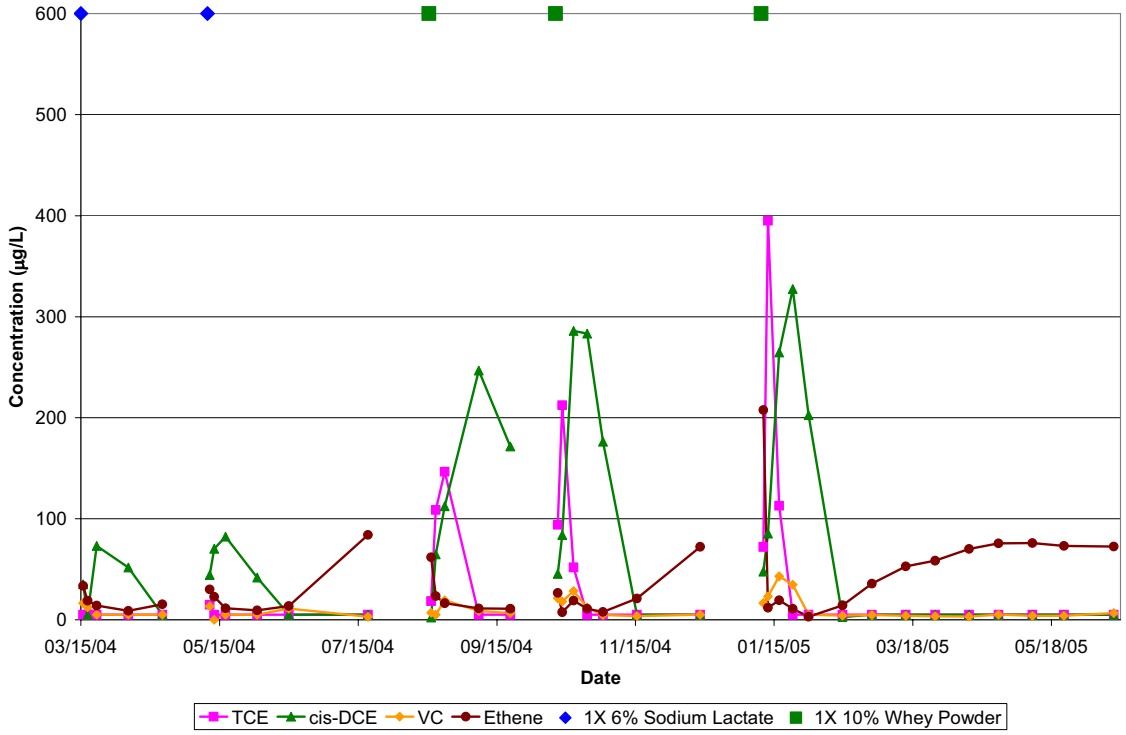

Figure A-28. Response of volatile organic compounds to sodium lactate and whey injections at TAN-25.

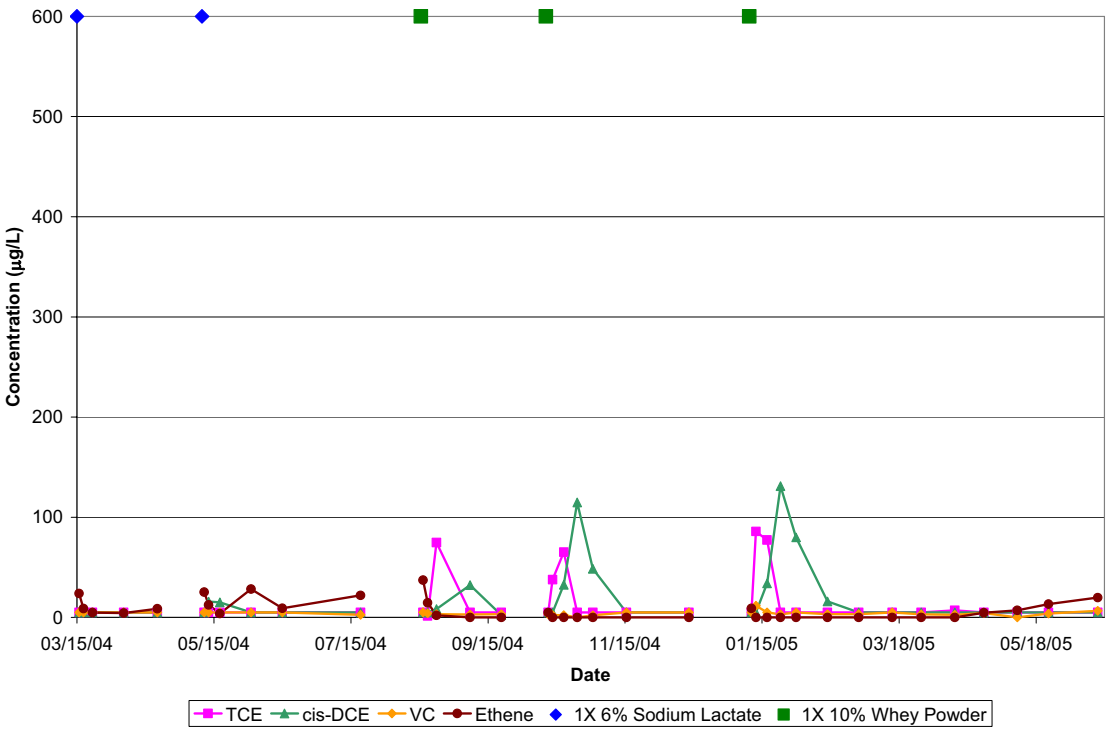

Figure A-29. Response of volatile organic compounds to sodium lactate and whey injections at TAN-31.

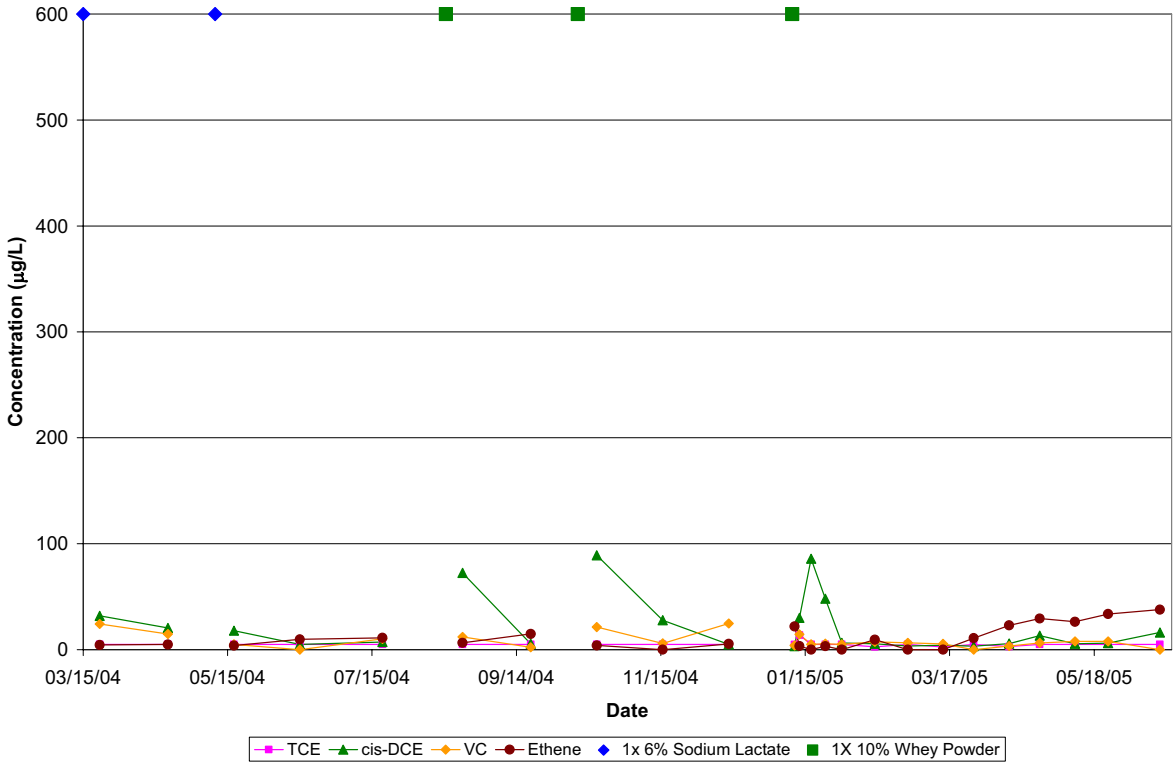

Figure A-30. Response of volatile organic compounds to sodium lactate and whey injections at TAN-1859.

Figures A-31 through A-35 illustrate the VOC molar response to electron donor injections at all of the AED sampling locations. Figures A-36 through A-38 illustrate the average total moles of VOCs and ethene for each sampling event averaged for the two sodium lactate injections, with the error bars representing one standard deviation. Day 71–73 does not have error bars because it was taken from one data point. These figures illustrate that the total molar concentration of VOCs and ethene is highest on Day 2 after the injection in TSF-05A and TSF-05B. In addition, this increase in total concentrations of VOCs and ethene correlates to large increases in the fractions of TCE, cis-DCE, and VC comprising 30–40% of the total VOCs present at TSF-05. In contrast these parent compounds comprise less than 20% in TSF-05B and 10% in TSF-05A by Day 36–38. A similar trend is observed at TAN-25 with the total molar concentrations of VOCs and ethene highest at Day 2, with the exception of the Day 71–73 sampling event. In addition, the total fraction of TCE, cis-DCE, and VC observed are highest right after an injection, comprising greater than 60% of the total molar mass by Day 8–10, which is subsequently reduced to less than 30% by Day 36 and to less than 5% by Day 71–73.

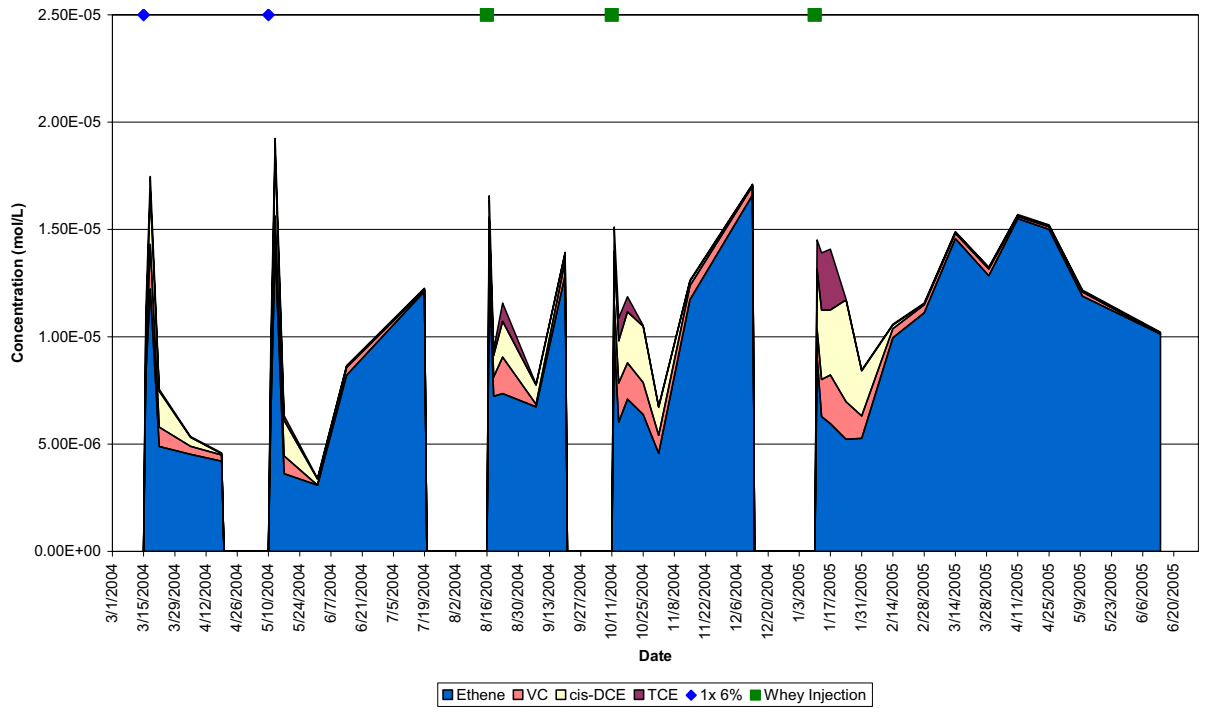

Figure A-31. Molar volatile organic compound charts illustrating response at TSF-05A to sodium lactate and whey powder injections.

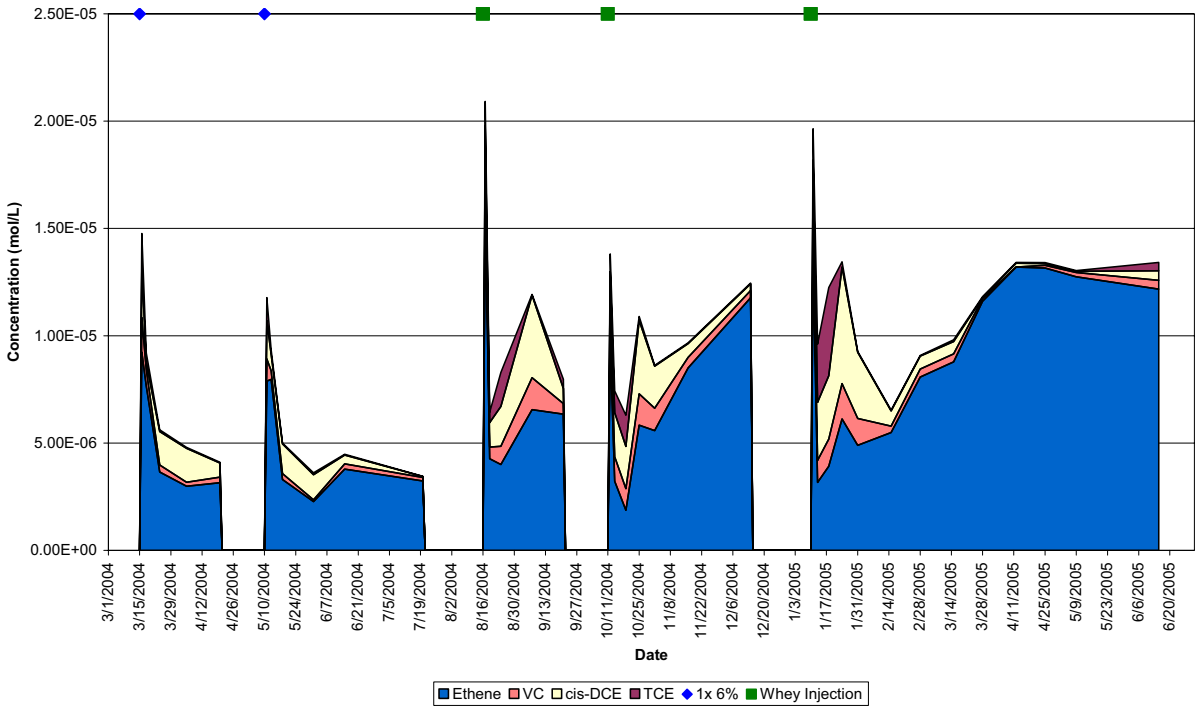

Figure A-32. Molar volatile organic compound charts illustrating response at TSF-05B to sodium lactate and whey powder injections.

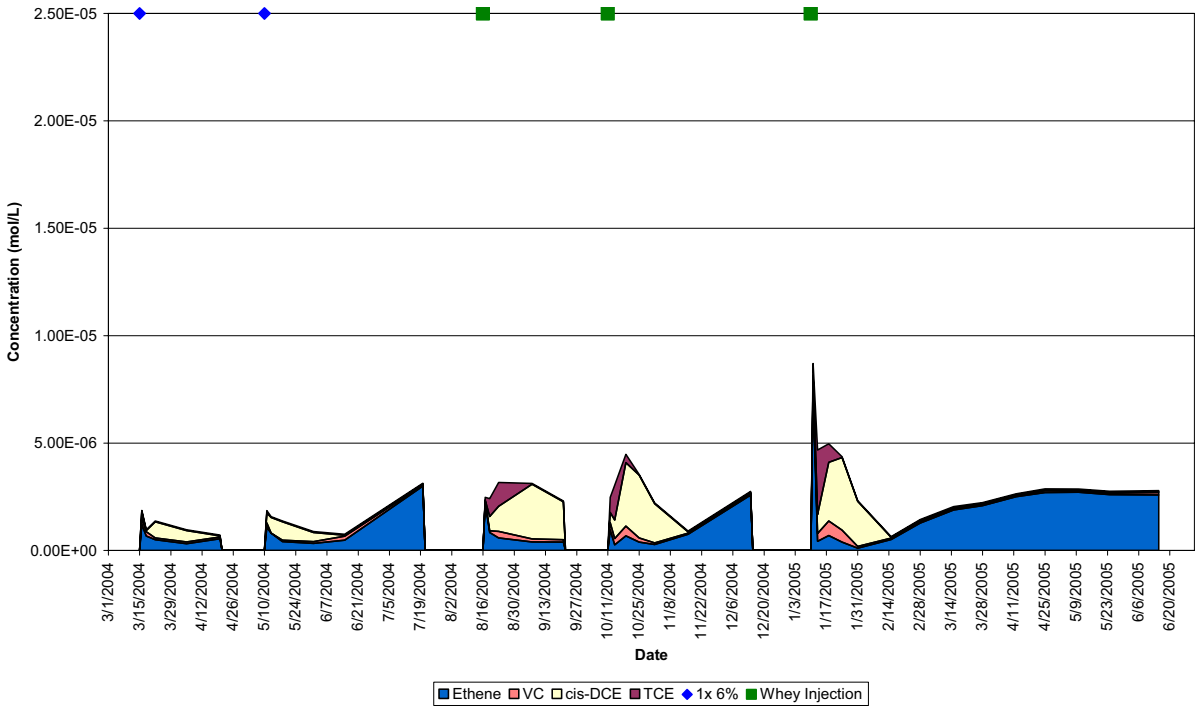

Figure A-33. Molar volatile organic compound charts illustrating response at TAN-25 to sodium lactate and whey powder injections.

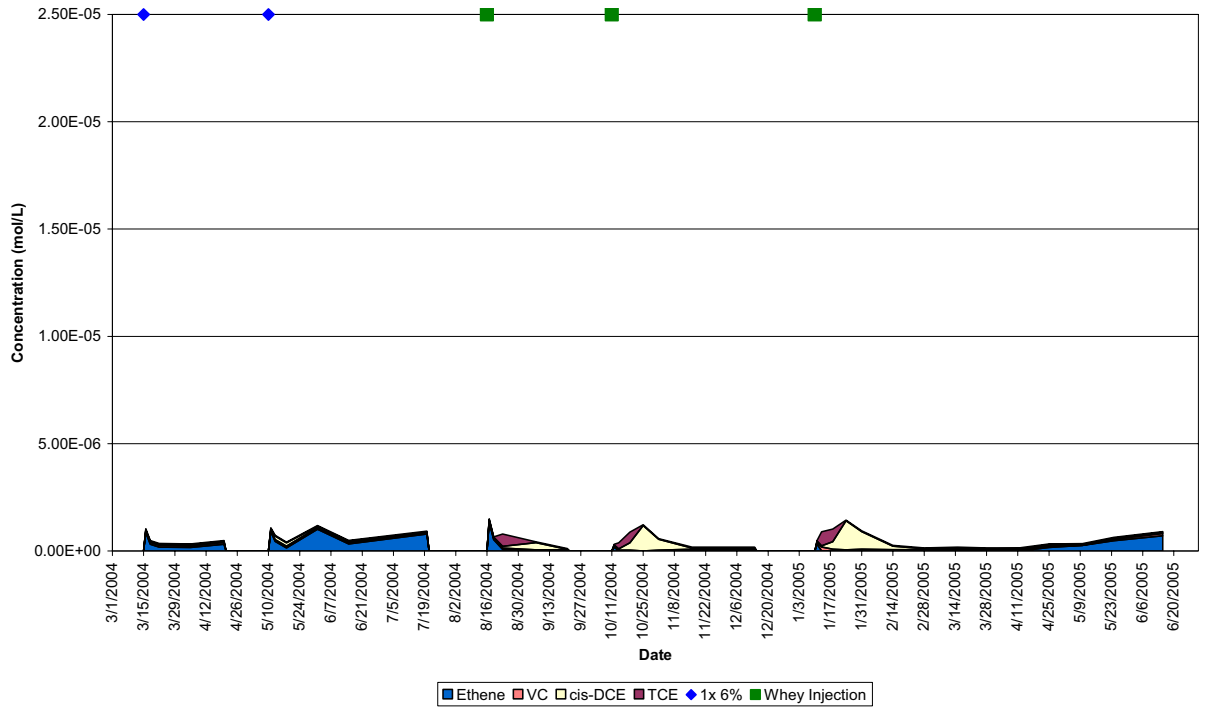

Figure A-34. Molar volatile organic compound charts illustrating response at TAN-31 to sodium lactate and whey powder injections.

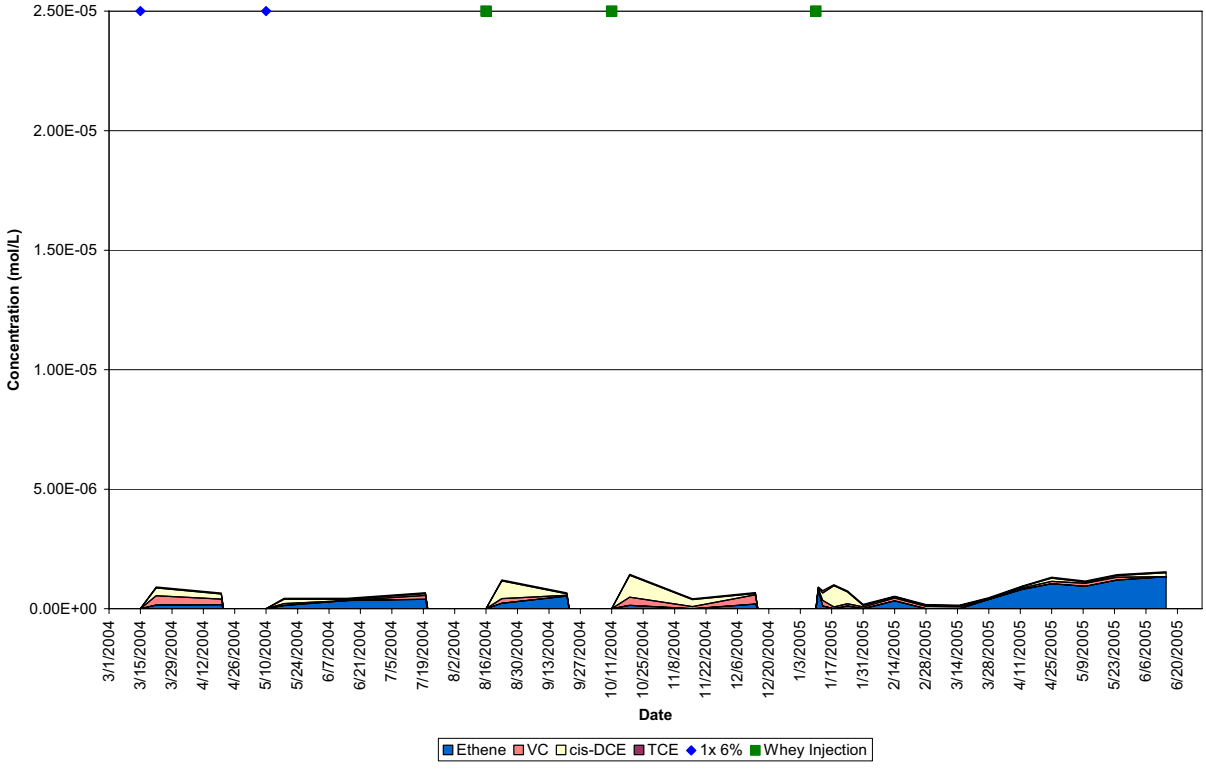

Figure A-35. Molar volatile organic compound charts illustrating response at TAN-1859 to sodium lactate and whey powder injections.

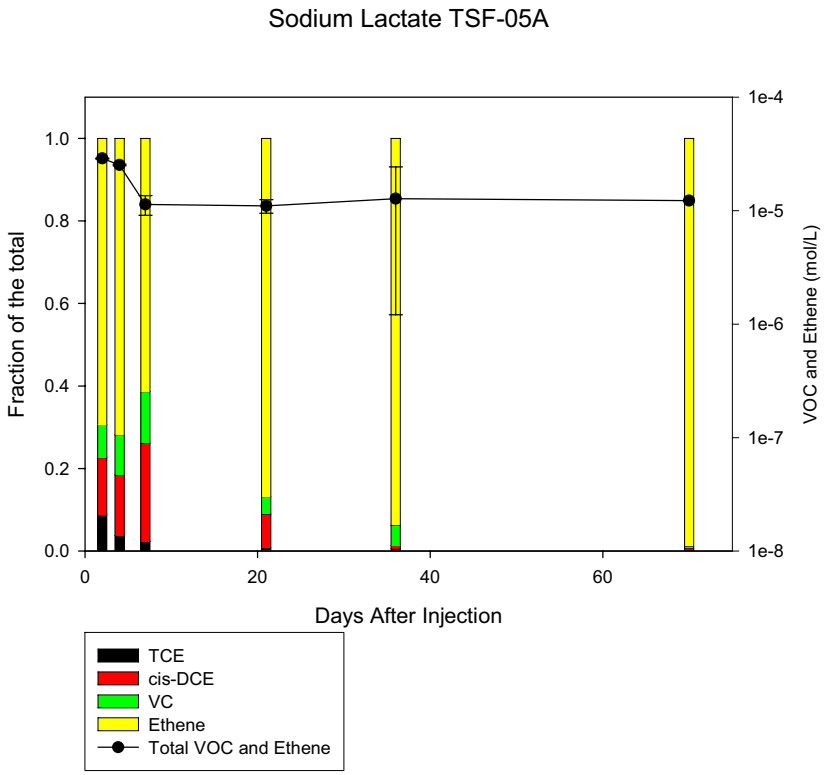

Figure A-36. Molar volatile organic compound charts illustrating the total molar concentration of VOCs and ethene and the relative fraction of each constituent at TSF-05A following a sodium lactate injection.

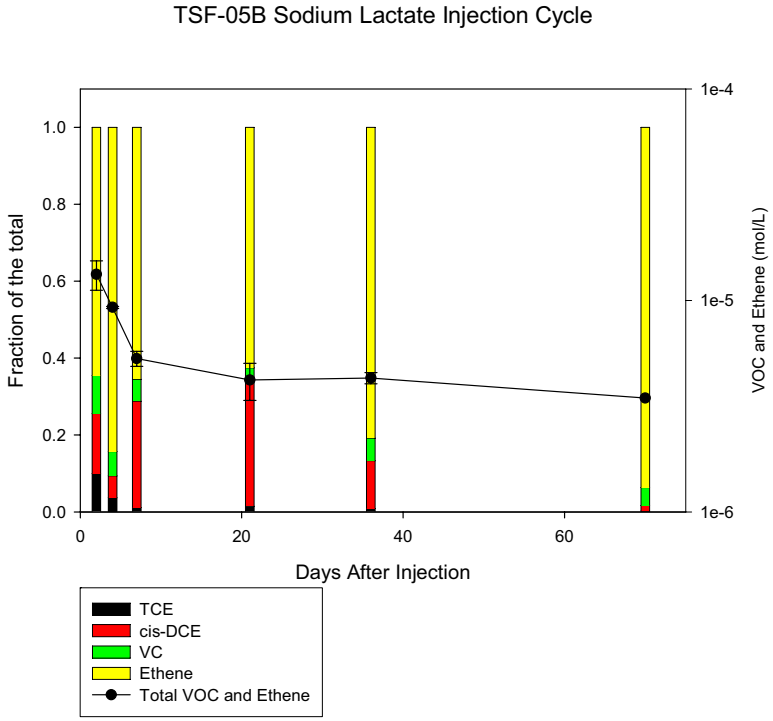

Figure A-37. Molar volatile organic compound charts illustrating the total molar concentration of VOCs and ethene and the relative fraction of each constituent at TSF-05B following a sodium lactate injection.

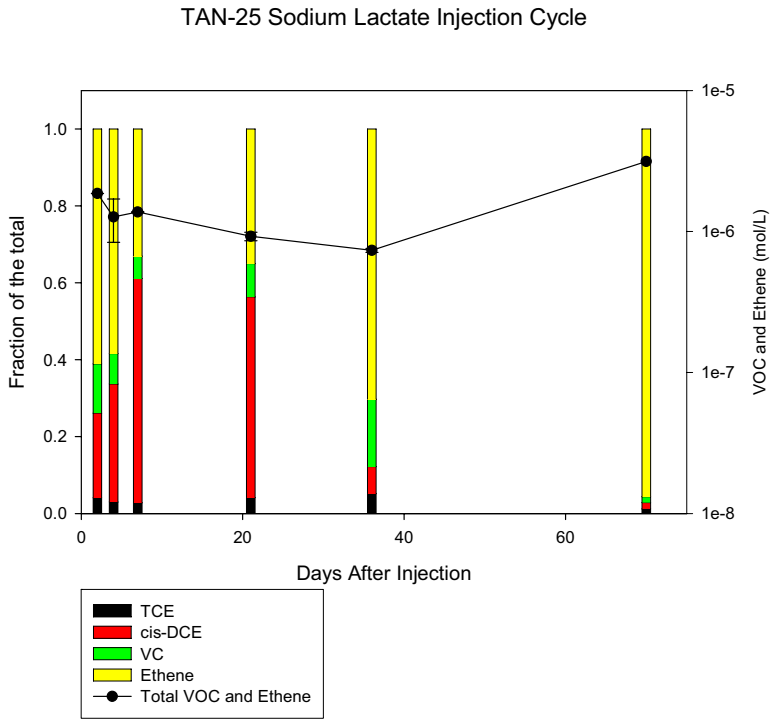

Figure A-38. Molar volatile organic compound charts illustrating the total molar concentration of VOCs and ethene and the relative fraction of each constituent at TAN-25 following a sodium lactate injection.

A-4.3.2 ARD and Enhanced Dissolution Results Following the Whey Powder Injections

TCE, cis-DCE and VC concentrations also increased following the whey powder injections. At TSF-05, the peak TCE concentrations increased dramatically following the third whey powder injection compared to the first two whey injections. For TSF-05A the peak TCE concentration was 131 µg/L following the first whey injection, 152 µg/L following the second whey injection, and 351 µg/L following the third whey injection. Likewise at TSF-05B, the peak TCE concentrations increased to 152 µg/L following the first whey injection, 191 µg/L following the second whey injection, and 538 µg/L following the third whey injection. This peak concentration was not always observed on Day 2, however, and often was observed on Day 4 and/or 8–10. This may have been due to the fact that sampling was difficult during the first week following whey powder injections due to the low surface tension and foamy conditions of the high concentration whey powder groundwater. The liberated TCE was quickly converted to cis-DCE, VC, and ethene. By Day 36–38, no TCE was detected, and cis-DCE and VC were present in low concentrations (<60 µg/L) compared to the mass of ethene at TSF-05A (361µg/L, 329µg/L, 312 µg/L) and TSF-05B (178 µg/L, 238 µg/L, 227µg/L) for all three whey injections.

As with contaminant concentrations at TSF-05, the peak VOC concentrations were observed on Day 4 and/or Days 8–10 at TAN-25 (Figure A-28) and TAN-31 (Figure A-29) following the three whey powder injections. At TAN-25, peak TCE concentrations were 147 µg/L after the first whey injection, 212µg/L after the second whey powder injection, and 395 µg/L after the third whey powder injection. Cis-DCE and VC concentrations were <50 µg/L. This liberated TCE was quickly degraded to cis-DCE with concentrations peaking at Day 15 for whey injection events 2 (283µg/L) and 3 (327µg/L). Ethene concentrations at TAN-25 declined following the first whey injection. Significant concentrations of ethene did not accumulate until Day 36–38 (11 µg/L, 21 µg/L, 14 µg/L), and the highest concentrations were observed during the last two Day 64–65 (72 µg/L, 53µg/L) and Day 120–121 (76 µg/L;

Figure A-28) sampling events. These data suggest that a longer period was observed at TAN-25 prior to the onset of ethene production than with sodium lactate.

A similar trend was observed at TAN-31, peak TCE concentrations (75µg/L, 65µg/L, 81µg/L) observed on Day 4 or 8–10 following the three whey injections. This was also followed by peak cis-DCE concentrations (115 µg/L, and 131 µg/L) by Day 15 following the second and third whey powder injections. Ethene concentrations, however, were below 5 µg/L until the May 2005 sampling when a slight increasing trend was noted (Figure A-29).

TCE and cis-DCE concentrations at TAN-1859 peaked on Day 4 for TCE (14 µg/L) and Day 8–10 for cis-DCE (86µg/L) after adding this well to the high frequency sampling schedule following the third whey injection. Ethene concentrations (9 µg/L) peaked at the Day36–38 sample event (Figure A-30).

The molar area charts (Figures A-31 through A-35) show the relative molar mass of the VOCs and ethene. In addition, Figures A-36 through A-41 represent the average total molar concentration of TCE, cis-DCE, VC and ethene and the fraction of the total each of these constituents comprised in groundwater for each of the AED sampling events. The error bars represent one standard deviation, and include all three samples collected on Days 2, 4, 8–10, 22 or 23, and 36–38, and two samples collected on Day 15, and 64–65. These data can be used to evaluate the mass balance between release of parent compound during an injection event and subsequent production of ethene. These data show that the average total molar concentration of VOCs and ethene was highest in the sampling events within a week of the injection for TSF-05. Again the highest fractions of TCE, cis-DCE, and VC were also observed after an injection, comprising greater than 40% of the molar mass in TSF-05A and 60% of the molar mass in TSF-05B. By Day 36–38, these constituents were reduced to less than 10% of the molar mass in TSF-05. A similar, although much less pronounced trend was observed at TAN-25. The total moles of VOCs and ethene were generally highest in the sampling events closest to the injection. The proportion of TCE, cis-DCE, and VC, however, was greater than 80% of the molar mass following the injection, compared to less than 60% by Day 36–38 and less than 5% by Day 64–65. The proportion of ethene made up greater than 95% of the total mass by Day 64–65. These data show a clear trend of increased total concentrations of VOCs following an injection followed by complete degradation of the liberated contaminants to ethene within 22–65 days.

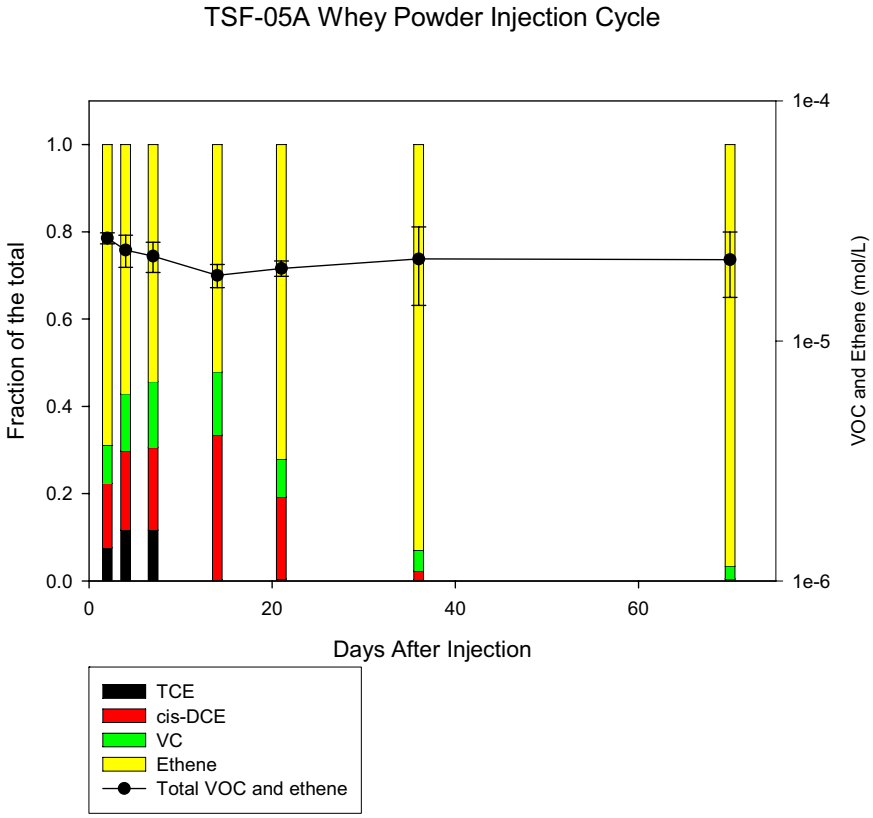

Figure A-39. Molar volatile organic compound charts illustrating the total average molar concentration of VOCs and ethene and the relative fraction of each constituent at TSF-05A following a whey powder injection.

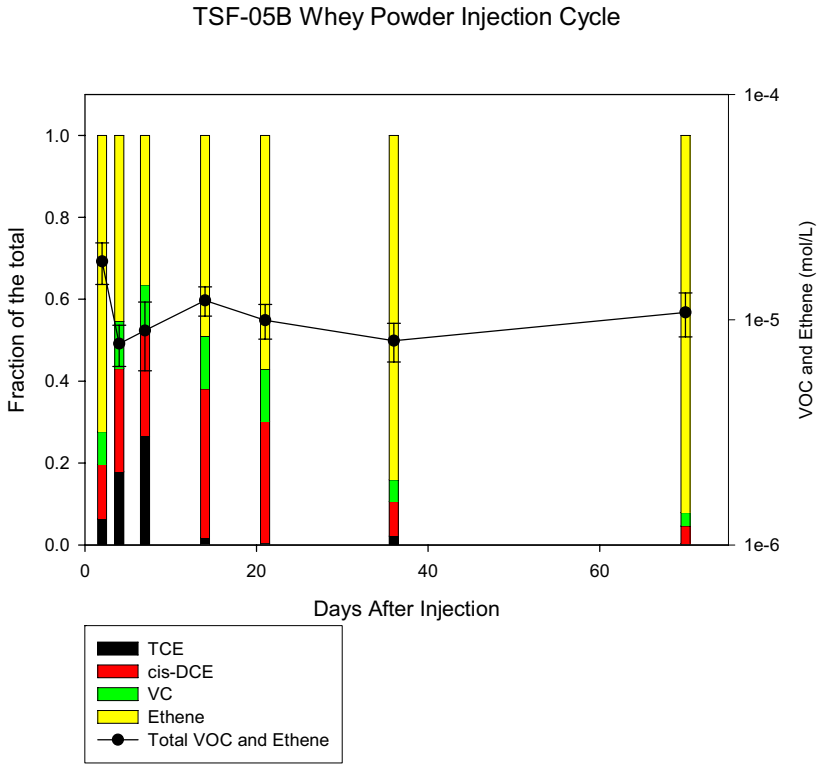

Figure A-40. Molar volatile organic compound charts illustrating the total average molar concentration of VOCs and ethene and the relative fraction of each constituent at TSF-05B following a whey powder injection.

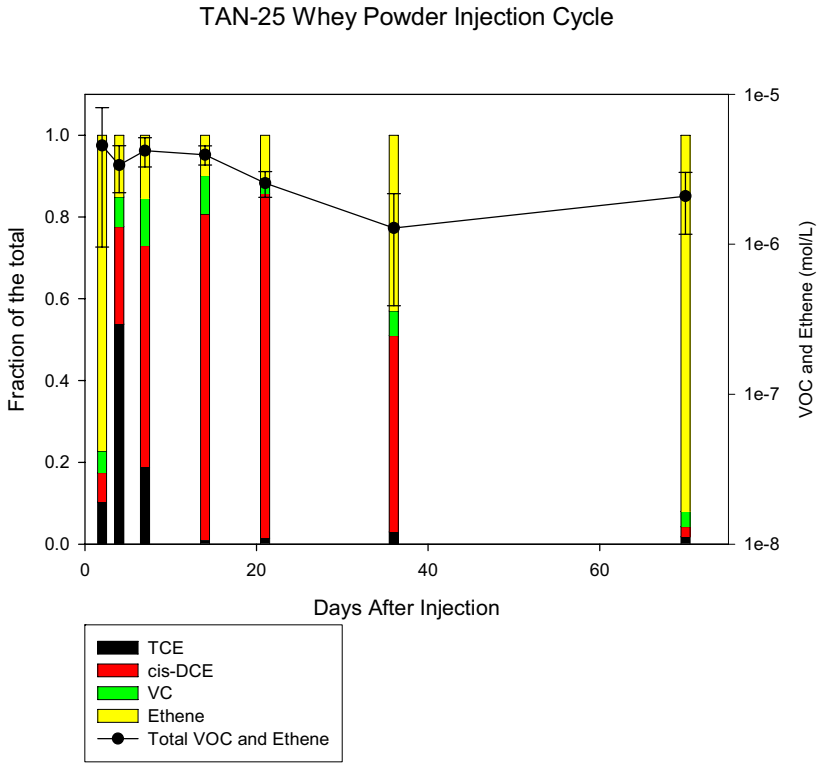

Figure A-41. Molar volatile organic compound charts illustrating the total average molar concentration of VOCs and ethene and the relative fraction of each constituent at TAN-25 following a whey powder injection.

A-4.3.3 Trans-DCE During the AED Optimization

In general, trans-DCE concentrations remained fairly stable throughout the sampled AED wells (Figure A-42) during the AED optimization. Concentrations observed on February 16, 2004, prior to the baseline sodium lactate injections were 215 µg/L in TSF-05A, 229 µg/L in TSF-05B, 170 µg/L in TAN-25, and 193 µg/L in TAN-31. Spikes in trans-DCE at wells TSF-05A, TSF-05B, and TAN-25 were observed 1 week after each sodium lactate injection. Concentration spikes were also observed in TAN-31 following the first sodium lactate injection but not after the second sodium lactate injection.

By Days 8–10 after the first whey powder injection, trans-DCE concentrations spiked again in TSF-05A. Trans-DCE concentrations at TSF-05B, TAN-25, and TAN-31 declined following the first whey injection and then increased back to similar concentrations observed at the beginning of the AED optimization. Similar trends were observed after the second whey injection at TSF-05A and TAN-25. Following the addition of the Day 15 sampling event, trans-DCE was observed to spike on this day at TSF-05B and TAN-31. Trans-DCE decreased back to levels observed at the beginning of the AED optimization following the spikes observed following the second and third whey powder injections. On Days 36–38 until the end of the AED optimization, trans-DCE continued to remain at concentrations similar to those observed in the past for all AED wells. In general, although trans-DCE remains recalcitrant throughout the biologically active zone, trans-DCE shows a steadily declining trend.

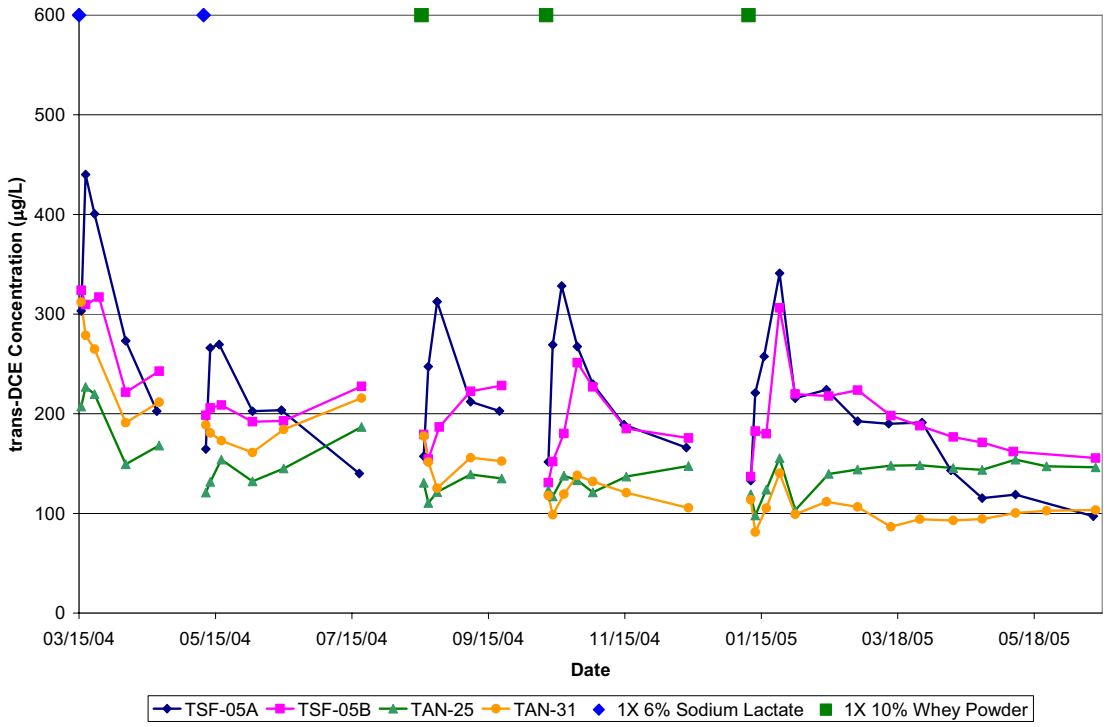

Figure A-42. Trans-DCE concentrations in alternate electron donor wells.

A-4.3.4 Ethene Methods Comparison

Observations during sample collection following the first whey powder injection indicated that during the period when the groundwater was foamy (Days 2, 4, and 8–10), samples with no headspace were difficult to collect. This was cause for concern because significant degassing could occur during groundwater sample collection. To test this idea, E/E/M was collected using two different sample collection methods; the "new" method (described in Section A-2.3.3) and the "old" method of filling 40-mL vials.

Ethene results for the old and new method at the AED wells are shown in Figures A-43 and A-44. The expected result was to see significantly higher ethene concentrations using the new method on Days 2, 4, and 8–10 (when foamy water was present and collection of samples with no headspace was difficult) as compared to Days 22 and 36–38 (when the water was not foamy). However, the data comparing the two methods demonstrates trends that are similar, with decreases in concentrations on Day 2 and 4. In fact, the data show that the values obtained initially were closer between the two methods than samples collected at later points during an injection cycle. Therefore, significant degassing did not appear to occur to a greater extend during periods when foam was present using the old method compared with the new method.

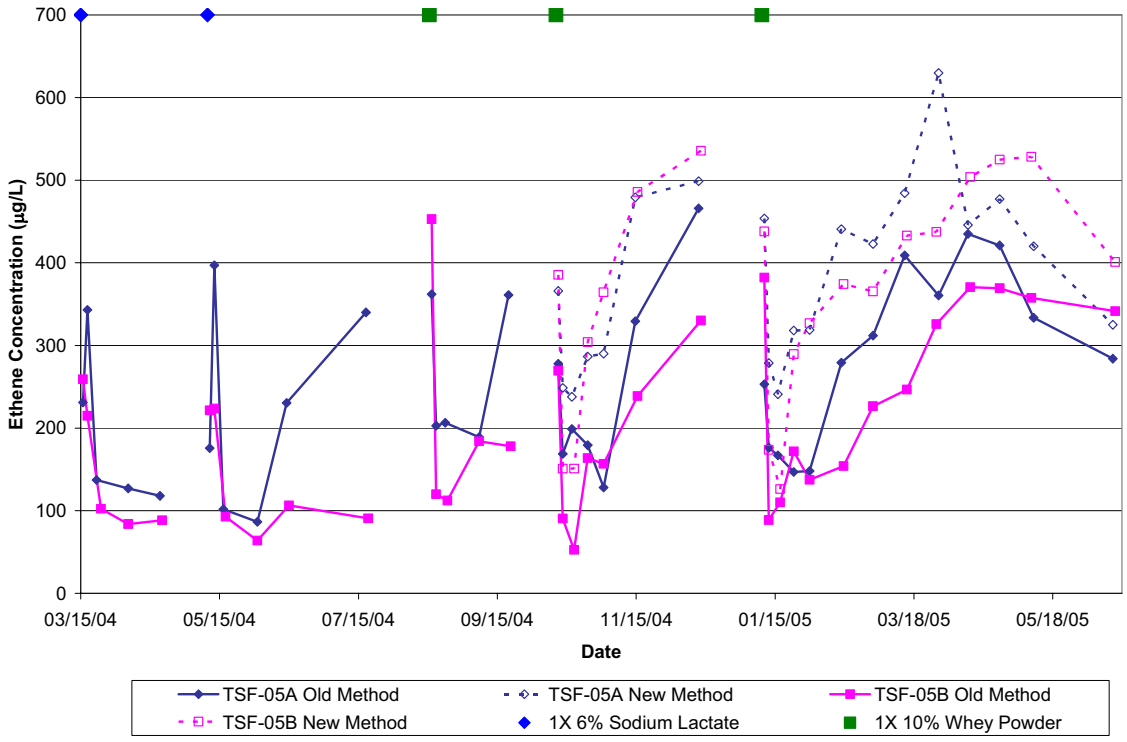

Figure A-43. Comparison of new and old ethene results at TSF-05A and TSF-05B.

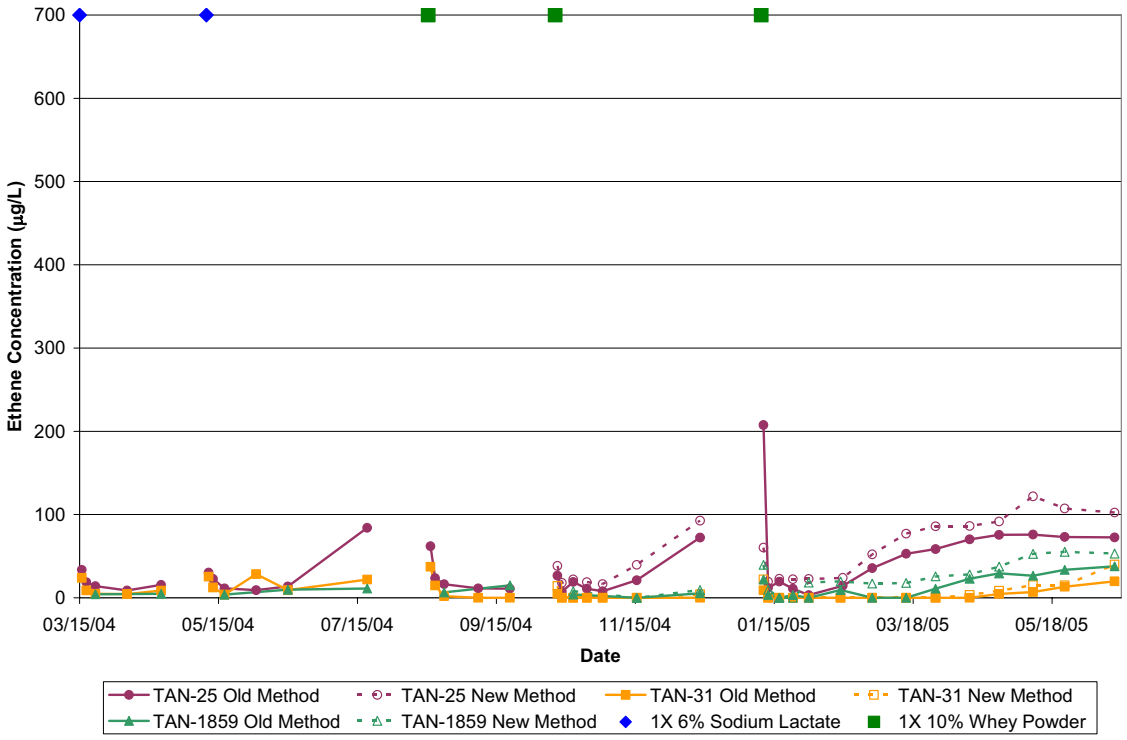

Figure A-44. Comparison of new and old ethene results at TAN-25, TAN-31, and TAN-1859.

Overall, the new method captured more ethene than the old method for all of the samples analyzed suggesting that it was a better method in general for collecting dissolved gas samples. At TSF-05A, the new ethene sampling method captured a wide range of ethene concentrations ranging from 2.5 to 126% more ethene than the old volatile organic analysis (VOA) vial method. The new method captured even more ethene at TSF-05B (ranging from 14 to 187% more ethene). At TAN-25, the new method captured ethene ranging from 17 to 619% more ethene than the old method, and at TAN-31, ethene was usually non-detect; however, when ethene was detected, the new method captured 4 to 194% more ethene than the old method. In addition, more ethene was captured using the new method at TAN-1859 (17 to 193% more ethene), except on January 24, 2005, when more ethene was captured utilizing the old method (3.3 µg/L vs. 0 µg/L). However, the new method is not recommended for collection of future ISB E/E/M samples because a change in sampling method would not allow accurate comparison to historical concentrations.

A-4.3.5 Reduced Interfacial Tension in TAN Groundwater

Difficulties with sample collection were encountered following the first whey powder injection because the purged groundwater was foamy. This made it impossible to fill sample bottles to no headspace because water had to run over the top of the bottle until the foam had dissipated. In addition, a meniscus would not form on the top of the sample bottle when it was full, which suggests lowered surface tension (ST) of the whey powder-containing groundwater compared to groundwater with no amendments.

In order to evaluate if a measurable difference in surface tension was evident in the groundwater samples containing high concentrations of whey, samples were collected to measure ST and interfacial tension (IFT) on Days 8–10 after the January 10, 2005 whey powder injection. IFT is defined as the work required to increase the interfacial (or contact) area between two fluids. ST is a special case of IFT in that one of the fluids involved is air. A high IFT indicates that the two fluids do not have an affinity for each other and that a significant input of energy will be required to increase their contact area. A low IFT implies that the fluids have an affinity for each other and that their contact area will be larger for a given energy input. In essence, a low IFT indicates that two fluids will easily dissolve into each other. IFT was measured between the groundwater samples and TCE dense non-aqueous phase liquid (DNAPL) in order to provide an indication of how readily TCE might dissolve from a residual phase into an aqueous phase containing high concentrations of whey. This was performed to validate that reductions in IFT between TCE DNAPL and whey powder solutions performed in the laboratory studies (Armstrong et al. 2003) could be verified using field groundwater samples.

Samples were collected at TSF-05B, TAN-25, and TAN-1859 in order to observe variability due to various concentrations of whey in the groundwater. In addition, samples were collected from TAN-28 as a groundwater control to compare results from the groundwater containing whey. A nanopure water sample was also run as the laboratory control. The results of the ST and IFT measurements (Table A-13) showed that IFTs were significantly decreased at all of the source area wells in comparison to the TAN-28 and nanopure controls, which were very similar. TAN-25 had the lowest IFT; followed by TSF-05B and TAN-1859. Therefore, lower IFT measurements were correlated to higher amounts of COD in the groundwater samples. These trends correlate with the relative increased TCE concentrations (in order from highest to lowest TCE concentrations) observed on Days 8–10 at wells TAN-25, TSF-05B, and TAN-1859, respectively (See section 4.3.1. and 4.3.2). ST measurements showed a similar pattern as the IFT values. The low ST measurements are a function of the higher concentration of electron donor present in the groundwater samples in the source area; therefore, a meniscus could not form when filling the VOA vials at these wells. TAN-28 was observed to have similar ST and IFT to the control. This should be expected since electron donor does not reach TAN-28 during or after an injection.

Table A-13. Surface tension and interfacial tension measurements from select in situ bioremediation wells and the control.

Well	Surface Tension[a] (mN/m)	Interfacial Tension[a] (mN/m)
TSF-05B	70.90 ± 0.03	37.78 ± 0.20
TAN-25	67.26 ± 0.03	33.99 ± 0.04
TAN-1859	71.99 ± 0.13	37.08 ± 0.36
TAN-28	72.98 ± 0.20	39.12 ± 0.20
Control	72.79 ± 0.04	39.42 ± 0.07

a. The data presented in this table represent the average of three trials and the standard deviation of those trials.

A-4.4 Radiological Monitoring

Previous ISB Annual Reports (INEEL 2002, 2003b; Armstrong et al. 2004) have indicated that radionuclides were being mobilized in the vicinity of TSF-05 in response to donor injections. Monitoring for Sr-90 and tritium after each injection during the AED optimization was performed for comparison of radionuclide mobilization following sodium lactate and whey powder injections.

A-4.4.1 Baseline Sodium Lactate Results

Monthly monitoring for Sr-90 at the AED wells was conducted during baseline sodium lactate injection events in March and May 2004. The increased sampling frequency of samples for Sr-90 analysis during the AED optimization shows peak concentrations immediately following injections. These peak concentrations are within the same ranges as concentrations reported historically throughout ISB operations at TSF-05A, TSF-05B, TAN-25, and TAN-31(Figure A-45).

Tritium was monitored at all the ISB well locations on a monthly basis. Tritium concentrations did not appear to correlate with sodium lactate injections and remained relatively stable throughout the AED optimization for all of the biologically active wells. Tritium concentrations in TAN-1859 increased to around 6,000 pCi/L in May and June of 2005; however, these concentrations are slightly higher than TAN-1859 concentration in November 2003 (5,210 pCi/L) and comparable to historic tritium concentrations at TSF-05A and TSF-05B in 2001 and 2002 (Figure A-46).

A-4.4.2 Whey Powder Results

Following the three whey powder injections, mobilization of Sr-90 was evidenced by elevated concentrations of Sr-90 in the AED wells (Figure A-45). As shown at TAN-25 (Figure A-47), decreases in pH correlate with spikes in Sr-90 following each whey powder injection. However, the elevated Sr-90 concentrations return to a steady state as pH stabilized in the well. Tritium concentrations remained relatively constant after the whey powder injections (Figure A-46).

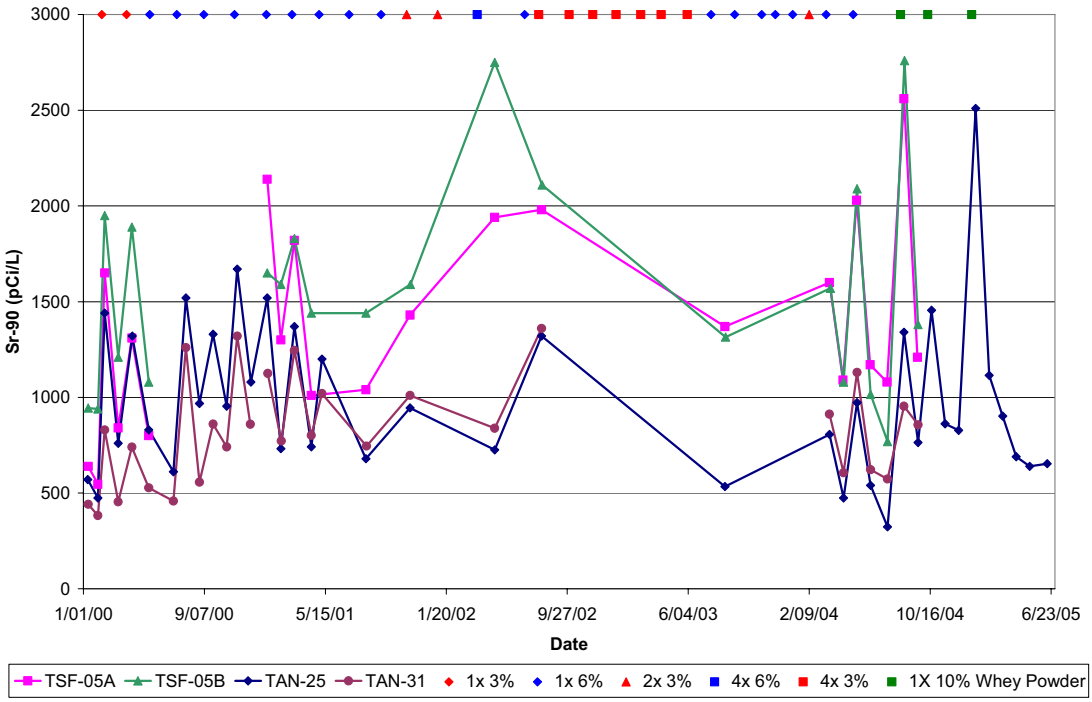

Figure A-45. Historical strontium-90 concentrations at TSF-05A, TSF-05B, TAN-25, and TAN-31.

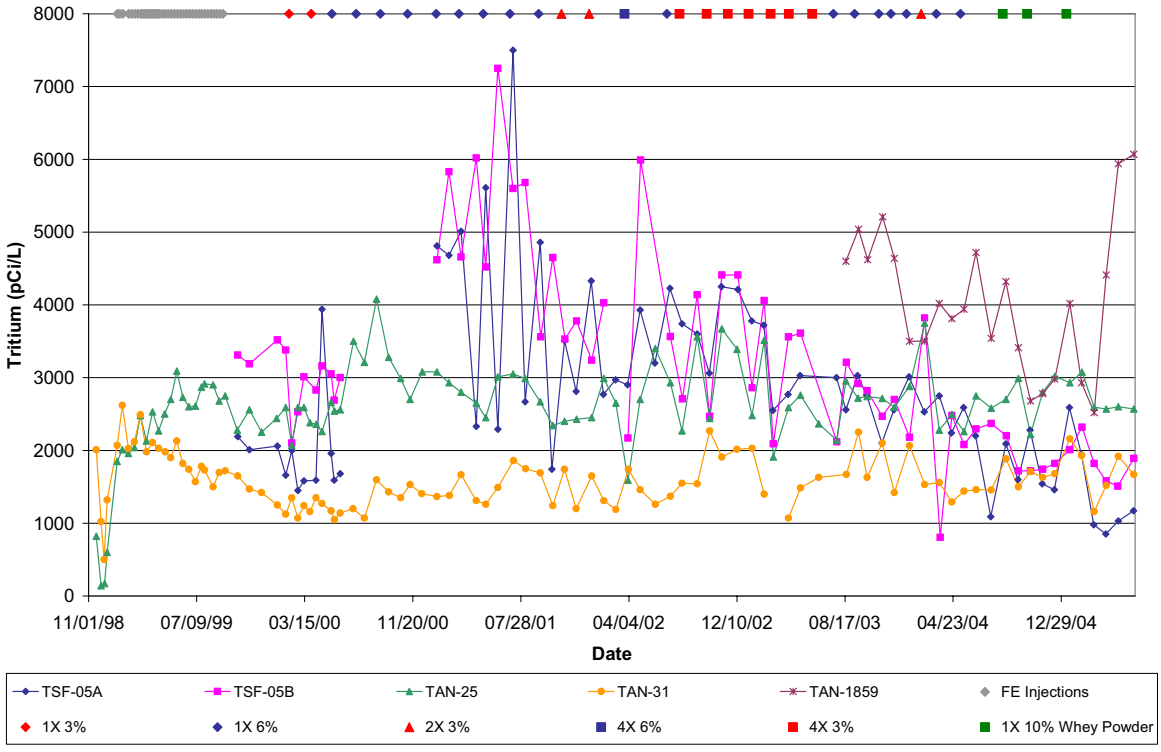

Figure A-46. Historical tritium concentrations at TSF-05A, TSF-05B, TAN-25, TAN-31, and TAN-1859.

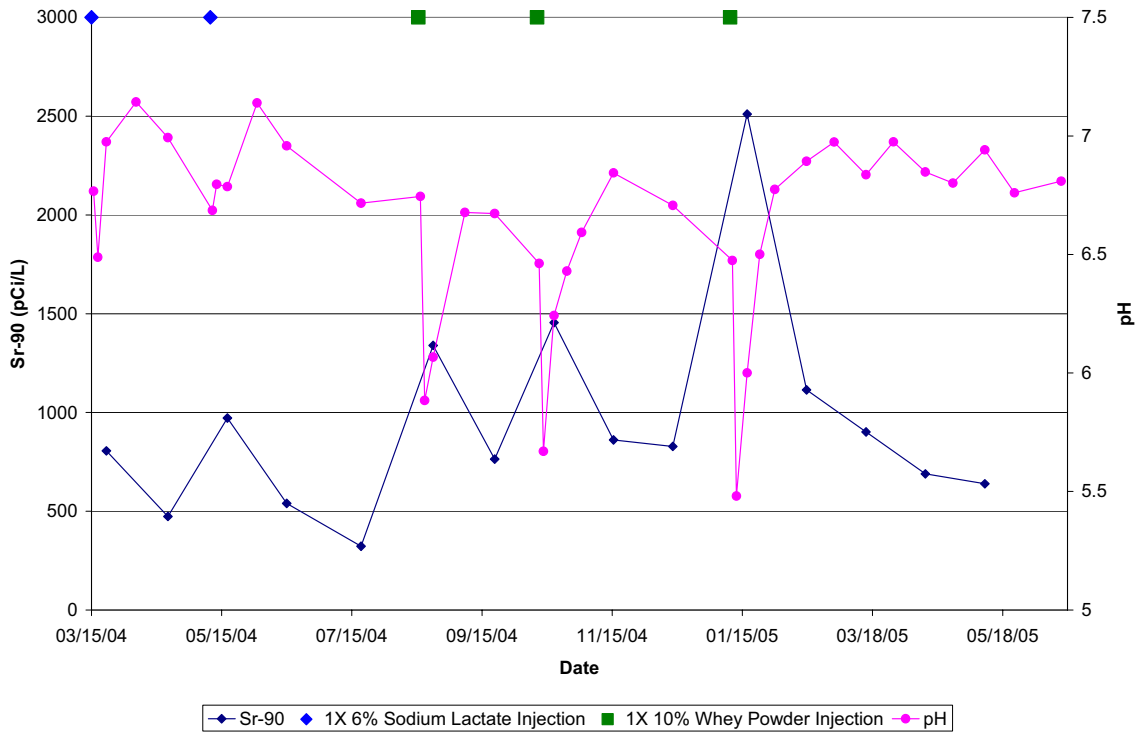

Figure A-47. Sr-90 and pH at TAN-25 during the alternate electron donor optimization.

A-4.5 Microbial Characterization

Studying microbial population dynamics over the course of an injection cycle has provided information about the populations responsible for lactate and lactose (whey powder) utilization. Understanding the dynamics of important sub-populations involved in degradation greatly enhances decision-making and more importantly, the ability to optimize the injection strategy to be more cost effective while maintaining an effective TCE-degrading biological community. Groundwater samples were collected from well TAN-25 during the AED optimization for deoxyribonucleic acid (DNA) extraction and molecular characterization, including terminal restriction fragment length polymorphism (T-RFLP) analysis of Bacterial and Archaeal populations and quantitative polymerase chain reaction (QPCR) for *Dehalococcoides.* T-RFLP is a technique that fingerprints the microbial community, providing estimates of the number of distinct microbial species as well as the relative abundance of each of those species. Alternatively, QPCR evaluates the abundance of a single species, in this case, *Dehalococcoides*. The purpose of collecting these samples was to determine the population dynamics that occur during electron donor injection cycles. Electron donor injections result in the sudden availability of high concentrations of readily degradable compounds (lactose or lactate) that stimulate rapid microbial growth. As a result of selective electron donor solutions and the resulting growth of sub-populations, shifts in the predominant microbial populations in the community likely occurred during electron donor availability.

A-4.5.1 T-RFLP Population Dynamics Following Baseline Sodium Lactate Injections

In a study conducted on groundwater samples collected from TAN-25 in November 2001 prior to the AED optimization, molecular characterization of the microbial community structure revealed populations likely responsible for the utilization of lactate and the reductive dechlorination of TCE to ethene at this location (Macbeth et al. 2005). Lactate additions have resulted in dechlorination of TCE to

ethene in two distinct stages. In the first stage, TCE is reduced to cis-DCE. Acetogenic bacteria and acetoclastic methanogens have been shown to dechlorinate TCE to cis-DCE fortuitously (Vogel and McCarty 1985; Egli et al. 1988; Wild et al. 1995; Holliger et al. 1992; 1999) and represent the largest fraction of both Bacteria and Archaea found at TAN. Also present at TAN are Sulfurospirillum multivorans, a bacterium known to derive energy from the reduction of TCE to cis-DCE (Sholz-Muramatsu et al., 1995; Luijten et al., 2003). The second stage of reductive dechlorination includes the reduction of cis-DCE to VC and VC to ethene (Maymo-Gatell et al. 1997; 1999; He et al. 2003). Dehalococcoides, the only isolated bacteria capable of complete reduction of TCE to ethene during growth, has been found consistently in every microbial sampling event conducted at TAN-25 since 2001.

The molecular characterization conducted at TAN-25 not only revealed the microbes potentially responsible for reductive dechlorination but also elucidated populations responsible for electron donor utilization. Table A-14 illustrates the results of the bacterial clone library used to identify individual T-RFLP fragments, commonly referred to as terminal restriction fragments (T-RFs), within the microbial community (Macbeth et al. 2005). The identification of specific dominant organisms is used again here as a point of reference for the AED lactate injections. Once T-RFs are identified, different organisms or groups of organisms within the population can be tracked with respect to presence and abundance over time.

Understanding the microbial structure and its shifts in response to degradation of both the electron donor and the residual source material allowed for the development of a conceptual model describing the function of, and interaction between, populations within the community. In addition, the potential impacts of those populations on reductive dechlorination were evaluated. The largest fractions of bacteria identified in TAN groundwater in 2001 were associated with acetate production and were implicated in syntrophic (cooperative interactions between several groups of organisms) or commensal (minimal cooperation, only one organism benefits) relationships with acetoclastic and acetate-assimilating methanogens and/or dechlorinators. Homoacetogens produce acetate as the primary end product from energy-yielding metabolism of a variety of substrates, including H_2 and CO_2 and/or lactate (Drake 1994). Homoacetogens not only provide a source of carbon (acetate) and energy (acetate and/or hydrogen) for reductive dechlorination but may provide a source of vitamin B12, an essential nutrient for *Dehalococcoides*, via corrinoid production. Based on the clone library analyses and identifications, methanogens at TAN were all either acetoclastic or acetate-assimilating. These data formed the basis for evaluating population dynamics during baseline lactate injections in subsequent years.

A-4.5.1.1 T-RFLP Bacterial Population Dynamics. T-RFLP profiles were generated at five time points following each of two lactate injections in March and May 2004 and were averaged together (Figure A-48). Table A-14 illustrates that a large percentage of bacteria identified previously using molecular methods in TAN-25 groundwater were associated with fermentation (within the class Clostridia). The following is an overview of the population dynamics of T-RFs.

The most dominant group of fermentative bacteria, both in the November 2001 studies and in these studies, was associated with T-RF 218, T-RF 224, and T-RF 300. These T-RFs were associated with Acetobacterium sp. strain HAAP-1. Figure A-49 illustrates the population dynamics of these T-RFs in response to lactate concentrations. For example, following the first lactate injection, the relative proportion of these T-RFs for the same time points (i.e., Day 2) were averaged for the two lactate injections; the error bars in the chart represent one standard deviation from the mean. The combined relative fractions of these T-RFs increased from a total of 3% of the total fluorescence on Day 2 after a lactate injection to a total of 24% of the total fluorescence on Days 8–10 after a lactate injection (Figure A-49, A). However, on Day 22 or 23, the relative fraction of these T-RFs declined back to approximately 3% of the total fluorescence.

Table A-14. Bacterial 16SrDNA clone identifications from Test Area North groundwater.

Clone ID	Frequency[a]	Putative Class and Order	Closest GenBank Match[b]	T-RF[c]
TANB55	32	*Clostridia/Clostridiales*	*Acetobacterium sp.* strain HAAP-1 (99%)	218, 224, 300
TANB77	6	*Clostridia/*unclassified		315
TANB7	5	*Clostridia/Clostridiales*	Clone WCHB1-82[d] (98%)	288
TANB5	4	*Clostridia/Clostridiales*	Clone DCE25[e] (98%)	230
TANB101	3	*Clostridia/Clostridiales*	*Clostridium haemolyticum* (96%)	520
TANB44	3	*Clostridia/Clostridiales*		464
TANB115	2	*Clostridia/Clostridiales*	*Clostridium puniceum* (98%)	520
TANB107	1	*Clostridia/Clostridiales*	Clone P3IB-23 (97%)	453
TANB127	1	*Clostridia/Clostridiales*	Clone vadinHB04 (95%)	295
TANB3	9	*Bacteroides/Bacteroidales*	*Cytophaga* sp. strain BD1-16 (95%)	90
TANB53	2	*Bacteroides/Bacteroidales*		90
TANB59	2	*Bacteroides/Bacteroidales*		92
TANB6	2	*ε-Proteobacteria/Desulfuromonadales*	*Dehalospirillum multivorans* (98%)	469
TANB142	1	*δ-Proteobacteria/Geobacterecia*	*Trichlorobacter thiogenes* (99%)	509
TANB18	2	*Spirochetes/Spirochaetales*	Clone DCE33[e] (99%)	123
TANB52a	2	*Spirochetes/Spirochaetales*		544
TANB22	7	*Candidate division OP11*	Clone d153[f] (99%)	262
TANB35	3	*Candidate division OP11*		262
TANB37	1	*Candidate division OP11*	Clone d153[f] (97%)	262
TANB108	1	*Candidate division OP11*		262
TANB84	1	*Candidate division OP3*		1489
TANB25	3	*Mollicutes/Acholeplasmatales*		279
TANDhc2[g]	N/A	*Dehalococcoides*	*Dehalococcoides* sp. FL-2 (100%)	514

a. Frequency of RFLP pattern out of 90 bacterial clones examined from TAN groundwater.
b. If the clone shares ≥95% sequence similarity with an organism or clone in the GenBank database then it is noted here along with the percent sequence similarity.
c. Size of terminal restriction fragment generated using *MspI* (bp).
d. From a chlorinated solvent-contaminated aquifer undergoing intrinsic bioremediation (Dojka et al. 1998 AEM 64:3869).
e. From a TCE- and DCE-dechlorinating consortium.
f. From a TCE-contaminated site undergoing intrinsic dechlorination (Lowe et al. 2002 FEMS ME 40:123).
g. Clone TANDhc2 was not a part of the general bacterial library, rather it was amplified separately with *Dehalococcoides*-specific primers (Hendrickson et. al. 2002 AEM 68:485).

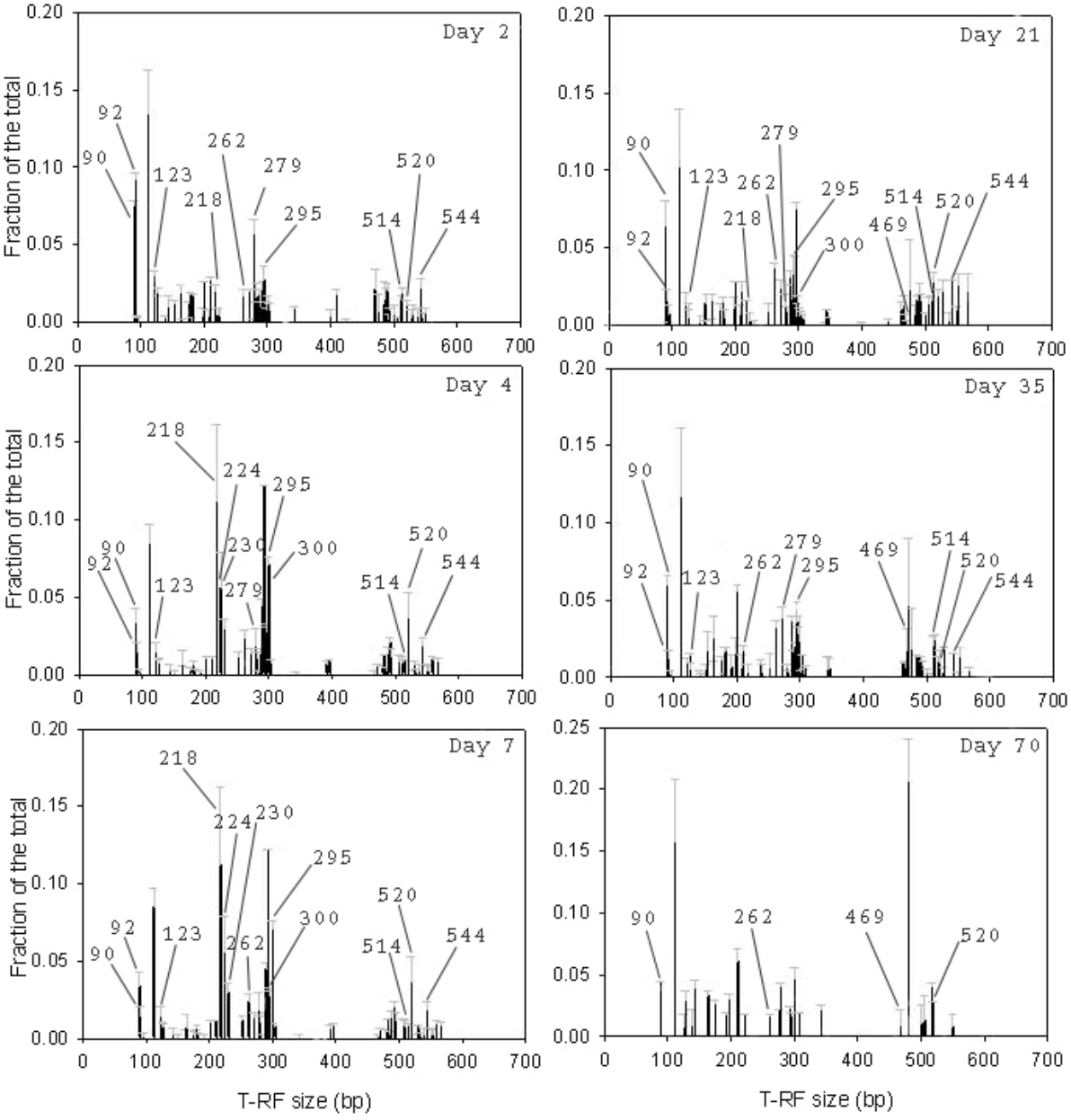

Figure A-48. Summary bacterial terminal restriction fragment length polymorphism profiles generated from samples collected following the lactate injections.

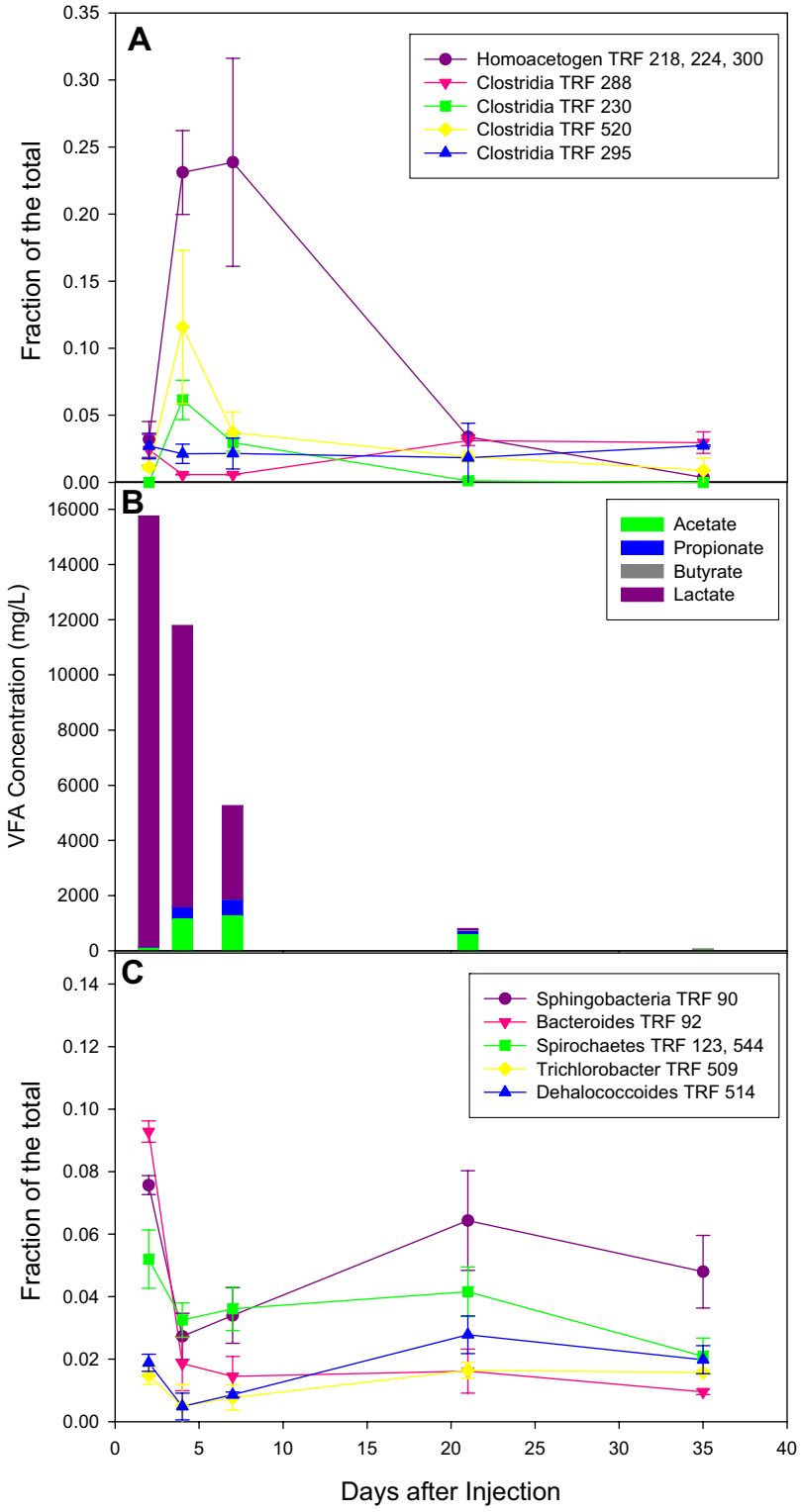

Figure A-49. A and C. Changes in population dynamics (TRFs) in TAN-25 following the injection of lactate in May and March 2004. B. The concentration of volatile fatty acids present in TAN-25 following lactate injection.

Other important fermentative bacteria were associated with T-RF 520 and were most closely related to Clostridium puniceium and Clostridium haemolyticum (Table A-14 and Figure A-49). This T-RF increased from a total of 1% of the total fluorescence on Day 2 after lactate injections to 12% of the total fluorescence on Day 4, and declined again to 4% on Days 8–10 (Figure A-49, A). Another organism that showed a significant response to the electron donor injection was an RDX-degrading homoacetogen (T-RF 230) associated with *Clostridia* and most closely with Clone DCE25. This T-RF, which was not detected on Day 2 after the injection, comprised 6% of the total fluorescence on Day 4 after an injection, 3% of the total fluorescence on Days 8–10, and was not detected in either the Day 22 or 23 or Days 36–38 T-RFLP profiles. An additional T-RF, 293, was not affiliated with any of the clones generated in the clone library. This T-RF, however, increased from 2% of the total fluorescence on Day 2 after the lactate injection to 15% on Day 4, 12% on Days 8–10, and 3% on Day 22 or 23, which suggests that it is also very responsive to lactate injections. These data indicate that these populations are active when lactate is the predominant source of energy. This is not surprising given that of all the biochemical pathways associated with lactate fermentation yield high energy that would be expected to support relatively fast growth rates (Fennell and Gossett, 1998, He et al. 1992). It would also be expected that fast growth rates of specific populations would lead to large population blooms when this compound is present.

Dynamics of other populations not associated with lactate fermentation are more stable compared to the population dynamics of lactate fermenters (i.e., T-RF peak heights don't change in response to injections). Other fermentative bacteria associated with Clostridia (T-RF 288, 295) did not respond to the lactate injection (Figure A-49, A). The utilization of propionate and acetate are less-energetically favorable reactions so they do not support the dramatic increases in growth observed with lactate. While concentrations of VFAs decrease significantly (Figure A-49) in the first 22 days, the growth of populations utilizing them (methanogens and propionate oxidizers) is significantly slower. These populations are limited by the low energy yield of the reactions they perform, particularly in the case of propionate utilization. The same is also true for Dehalococcoides (T-RF 514), whose growth is significantly limited by the availability of TCE (Figure A-49, C), which appeared in the profiles with similar peak heights (abundance) during and following lactate injections

In the T-RFLP profiles generated from TAN-25 groundwater, T-RF 90 was associated with the *Sphingbacteria*, T-RF 92 was associated with *Bacteroides*, and T-RFs 123 and 544 were associated with *Spirochaetes* (Table A-14). The abundance of *Homoacetogen*, various *Clostridia*, *Sphingbacteria*, *Bacteroides,* and *Spirochaetes* were plotted over time to determine the relative abundance (proportion of total) of each group during injections (Figure A-49). Relative bacterial abundance decreased during periods of lactate fermentation due to the large population increase of lactate fermenters (0 to 7 days). Otherwise, the relative proportions of these bacteria within the T-RFLP profile remained fairly stable over time (7 to 35 days).

A-4.5.1.2 T-RFLP Archaeal Population Dynamics. The relative proportions of the Archaeal populations in the T-RFLP profiles did not change over the duration of the lactate sampling period (Figure A-50). The error bars in Figure A-50 represent the combined difference between the corresponding sampling points following the two lactate injections. One peak, associated with an acetate-utilizing methanogen, was the dominant fragment for all sampling events. This suggests that the methanogenic microbial community structure did not change much over time and was relatively independent of the carbon substrate amendment.

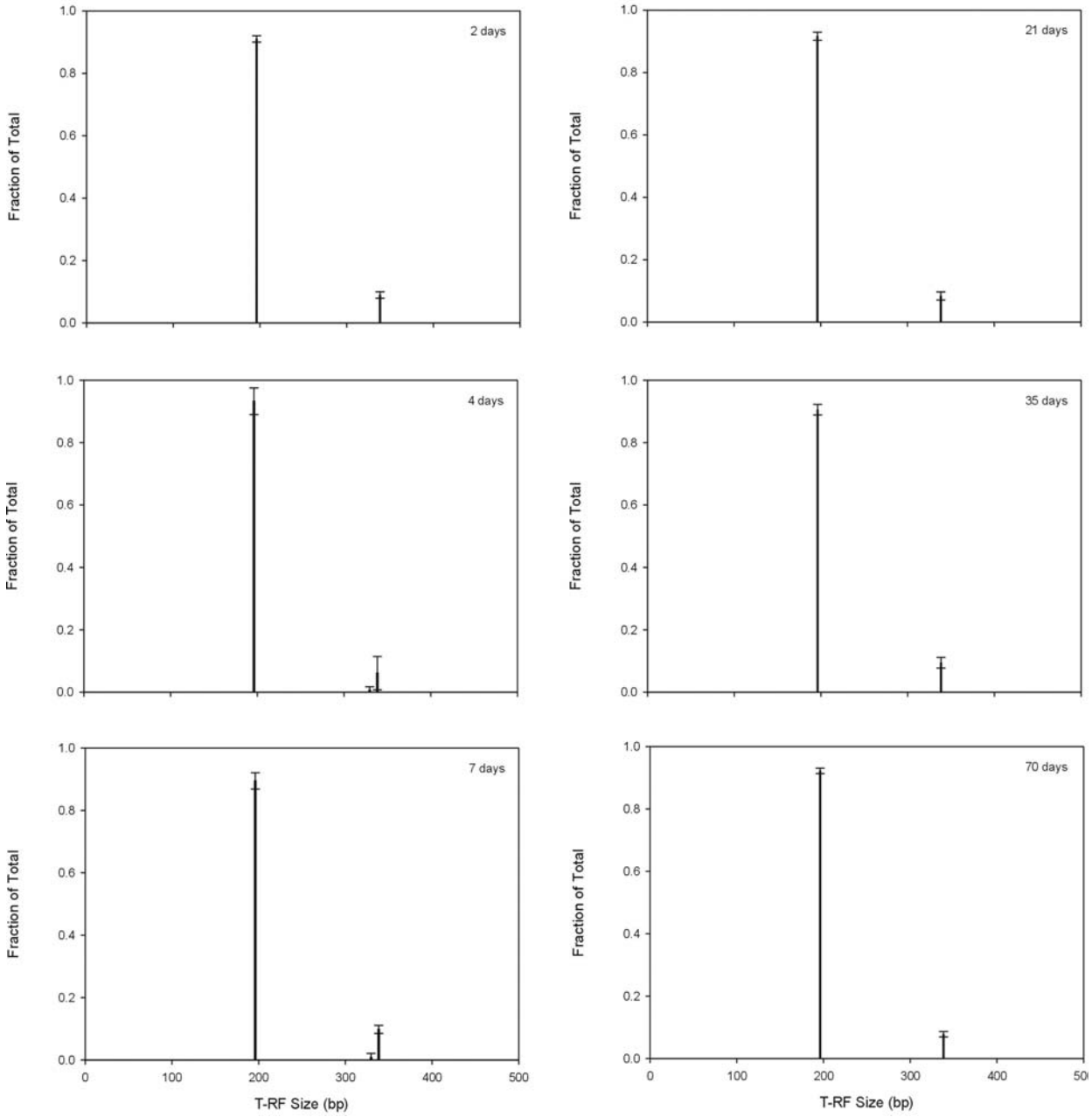

Figure A-50. Archaeal terminal restriction fragment length polymorphism profiles generated from samples collected following the first (March 2004) and second (May 2004) sodium lactate injections.

A-4.5.1.3 Diversity of TAN-25 Bacteria Following Two Sodium Lactate Injections.

Table A-15 describes the diversity assessment of the samples collected for molecular T-RFLP analysis. The first column identifies the date the sample was collected; column 2 identifies the corresponding days after injection; column 3 identifies the number of T-RFs (taken as an indicator for the number of species); columns 4 through 6 identify the diversity parameters; and column 7 presents the similarity between the two T-RFLP profiles that correspond to the same point following a lactate injection (i.e., Day 2). Diversity was evaluated by two measurements, Shannon-Weiner (Margalef 1958) and Simpsons indices (Simpsons 1948). The Shannon-Weiner index evaluates the diversity, accounting for species richness and

proportion as well as the evenness of the community (Column E in Table A-15), while the Simpsons index evaluates diversity based on the abundance of the most common species. According to these data, diversity was generally lower on the Day 4 and Days 8–10 sampling events during the period when lactate fermentation was the greatest. Diversity was also lower on the last sampling day, Day 72, when the carbon source and secondary VFAs were depleted, cell abundance diminished, and in general the conditions could be considered extreme with respect to microbial growth. The Shannon-Weiner function for the T-RFLP profiles was also generally lowest for the Day 4 and Days 8–10 samples. These data are consistent with the conceptual model of lactate stimulating enrichment of lactate-fermenters and reducing the overall diversity of the community relative to time periods when lactate is not present.

Table A-15. Terminal restriction fragment length polymorphism diversity assessments at TAN-25 following two (March and May 2004) sodium lactate injections.

Date Sampled	Days after Lactate Injection	S (T-RFs)	Shannon-Wiener	Simpsons	E	Jaccard coefficient
3/16/2004	2	59	5.23	0.96	0.89	0.72
5/11/2004	2	44	4.83	0.95	0.88	
3/18/2004	4	40	4.11	0.91	0.77	0.60
5/13/2004	4	45	4.57	0.94	0.83	
3/22/2004	8	46	4.47	0.93	0.81	0.75
5/18/2004	9	54	5.00	0.95	0.87	
4/5/2004	22	58	5.25	0.96	0.90	0.77
6/1/2004	23	55	5.27	0.97	0.91	
4/20/2004	37	62	5.33	0.96	0.90	0.70
6/15/2004	37	47	5.07	0.96	0.91	
7/20/2004	72	27	4.12	0.91	0.87	NA

The reproducibility of the T-RFLP method for both Bacteria and Archaea was assessed by determining the Jaccard coefficient for the composite T-RFLP profiles generated for comparable days following a lactate injection (Dunbar et al. 2001). Jaccard coefficients are based on binary variables of peak presence and are equal to the ratio of matching T-RFs to the total number of T-RFs present in the profiles being compared. The values range from 0 to 1, with a value of 1 meaning that all of the T-RFs are identical in the profiles being compared. These data suggest that the T-RFLP profiles were very similar, with Jaccard coefficients ranging from 0.70 to 0.77, with the exception of the Day 4 T-RFLP profiles, which had a Jaccard coefficient of 0.60. These data suggest that the T-RFLP profiles are remarkably reproducible in terms of generating the same T-RFs following a lactate injection.

A-4.5.2 T-RFLP Population Dynamics Following Whey Powder Injections

For reductive dechlorination, whey additions have resulted in dechlorination of TCE to ethene. Much like sodium lactate degradation, TCE is reduced to cis-DCE, likely by acetogenic bacteria and acetoclastic methanogens (Vogel and McCarty 1985; Egli et al. 1988; Wild et al. 1995; Holliger et al. 1992; 1999), and subsequently reductively dechlorinated to VC or ethene (Maymo-Gatell et al. 1997; 1999; He et al. 2003), as evidenced by the production of ethene following all three injections (Section A-2.2). *Dehalococcoides*, the only isolated bacteria capable of complete reduction of TCE to ethene, was consistently found in the AED treatment zone following whey injections, as determined by QPCR.

Understanding the microbial structure and its shifts over time in response to degradation of both the electron donor and the residual source material allows for the development of a conceptual model of the populations within the community. While clone library analysis has not yet been performed following whey powder injections, evaluating the changes in dominant fractions of the community over time following these injections can provide valuable information about the populations and their potential impacts on reductive dechlorination. Bacteria identified in TAN groundwater following baseline injections in 2001 were used as a means of evaluating population dynamics following whey powder injections.

A-4.5.2.1 T-RFLP Bacterial Population Dynamics. T-RFLP profiles were generated at up to seven time points following two of the whey powder injections in October and January 2005, and averaged together (Figure A-51). As a result of the transition of the microbial community from one dominated by organisms that utilized lactate as a primary source for growth to one that utilized lactose, the results following the first whey powder injection are markedly dissimilar than those following the second and third injections. As a result, the data generated (microbial analyses specifically) following the first whey powder injection is being considered a transition phase between the two electron donors and is not averaged together with the results following the other two injections, which were much more similar with respect to microbial community dynamics. Therefore, the following results will focus on the average of those from the second and third whey powder injections and will not include results from the first whey powder injection.

The dominant groups of bacteria, following whey powder injections were distinct from the populations following sodium lactate injections and from the November 2001 studies (Figure A-52, A, C). Several T-RFs showed significant responses following whey powder injections. For example, T-RF 155, unidentified, was the dominant T-RF during periods when lactose was available and utilized (Figure A-52, A). The relative fraction of T-RF 155 decreased from 61% of the initial population to 29% on Day 14, and continued to decrease to 1% on Day 21. In addition, T-RFs 520, 484, 518 also responded to the utilization of lactose (Figure A-52, A), however the responses of each of these sub-populations was not as dramatic as T-RF 155. T-RF 484 decreased from 6% of the total initial population to 1% on Day 14, while T-RF 520 decreased from 22% on Day 4 to less than 1% on Day 35. Other important bacteria were associated with T-RF 554, which dominated in the later samplings following whey powder injection (A-52, C). Specifically, T-RF 554 was non-detect during the samplings on Days 2, 4, and 7, following whey injections, but predominated the population on Days 21 (6%) and 35 (29% of the total population).

These data indicate that the microbial community utilizing lactose is significantly different than the community utilizing the degradation products of lactose. Additionally, it is important to note that none of the predominating bacteria that were identified, based on T-RFs, following the three whey powder injections corresponded to those that predominated following sodium lactate additions.

Dynamics of other populations presumably not associated with lactose fermentation were more stable (i.e. T-RF peak heights do not change in response to injections), as evidenced by little to no changes in the overall fraction of the total population each subpopulation represented (T-RFs 93, 296; Figure A-52, C).

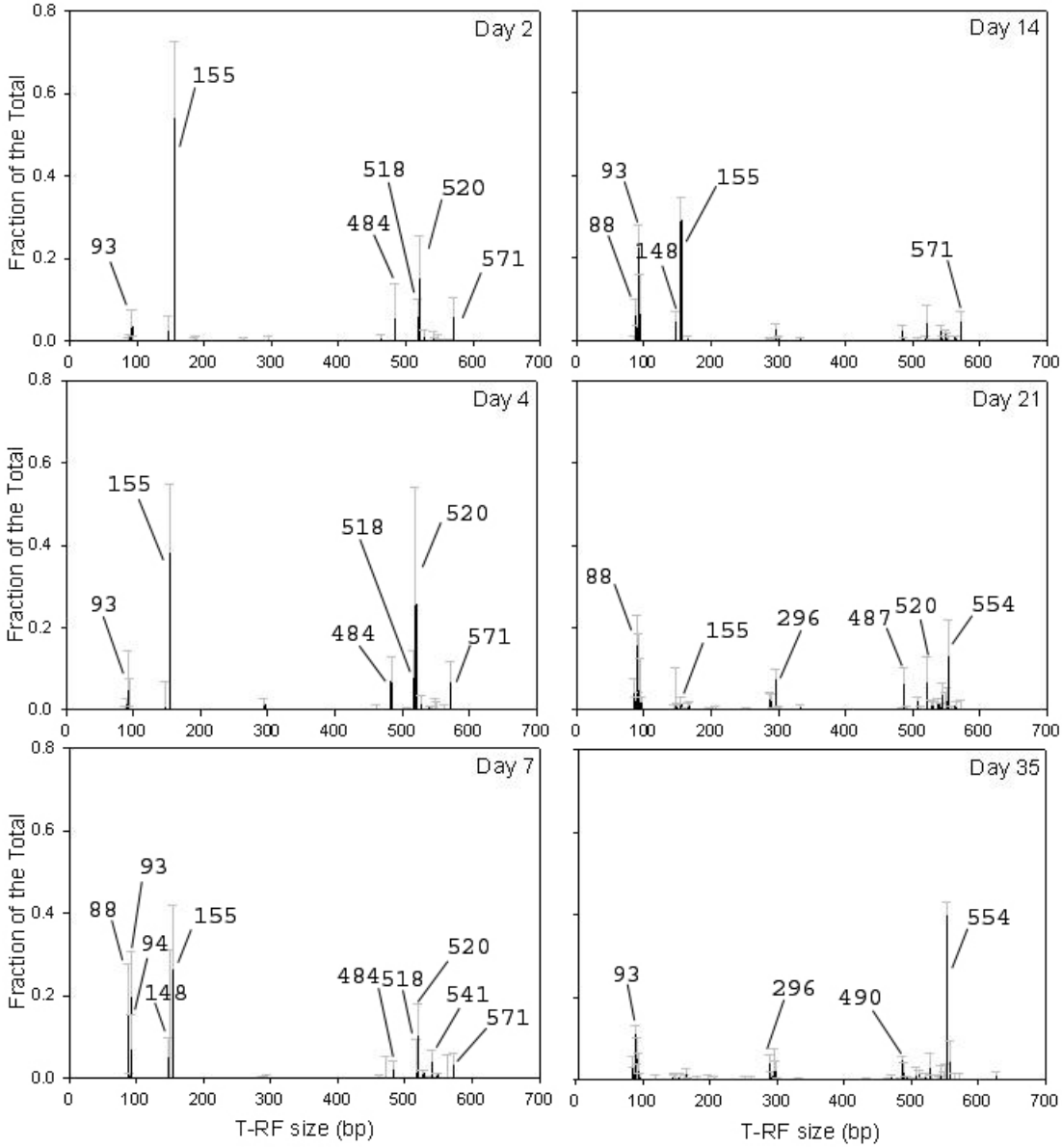

Figure A-51. Summary bacterial terminal restriction fragment length polymorphism profiles generated following the whey powder injections.

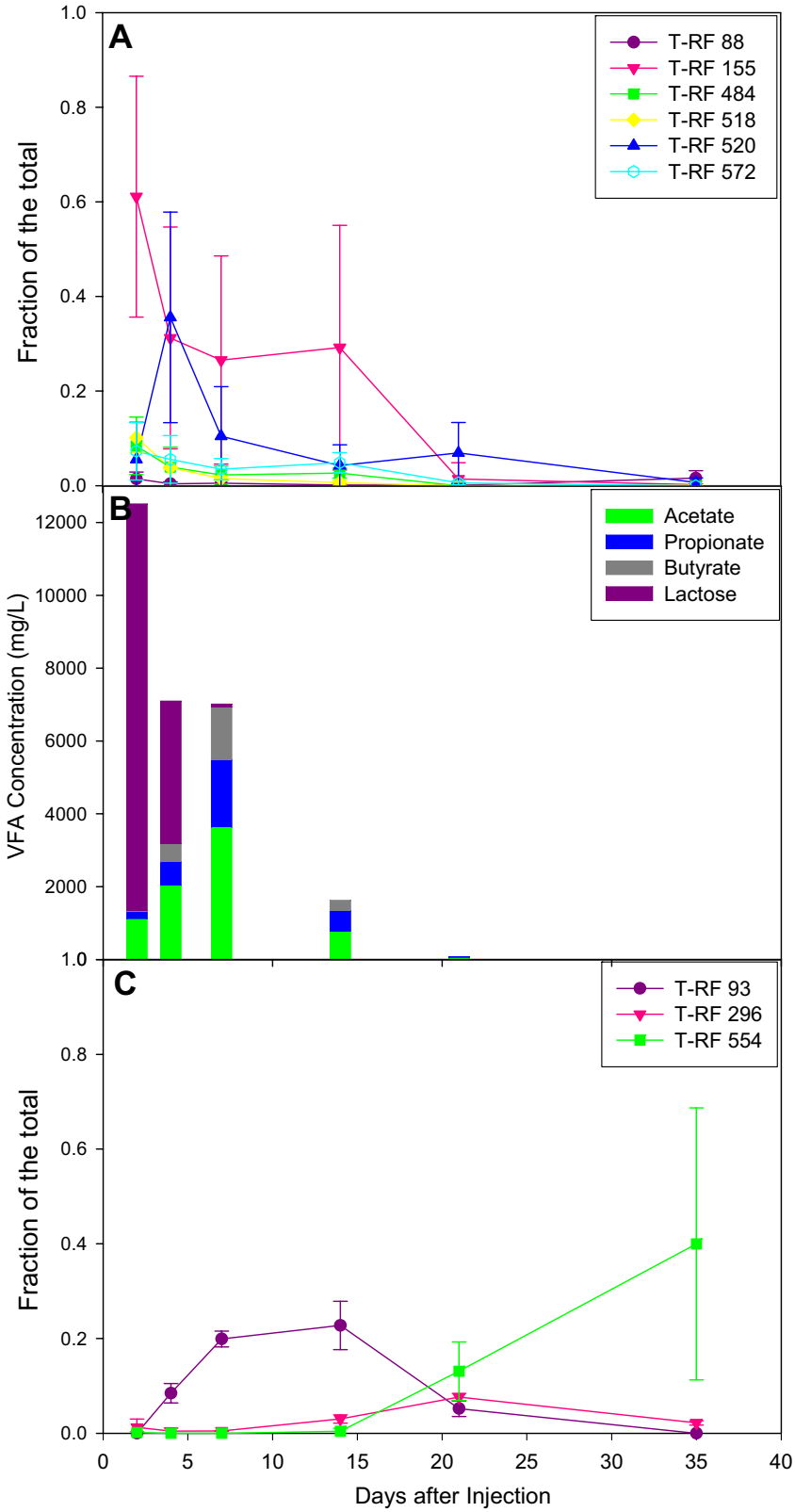

Figure A-52. A and C. Changes in population dynamics (TRFs) over time, following the whey powder injections. B. Concentrations of available volatile fatty acids at TAN-25 following whey injections.

A-4.5.2.2 T-RFLP Archaeal Population Dynamics. The relative proportions of the Archaeal populations in the T-RFLP profiles did not change over the duration of the whey powder sampling period (Figure A-53). The results of this analysis were similar to that following the sodium lactate injections with one subpopulation dominating, with little change over time following the injection.

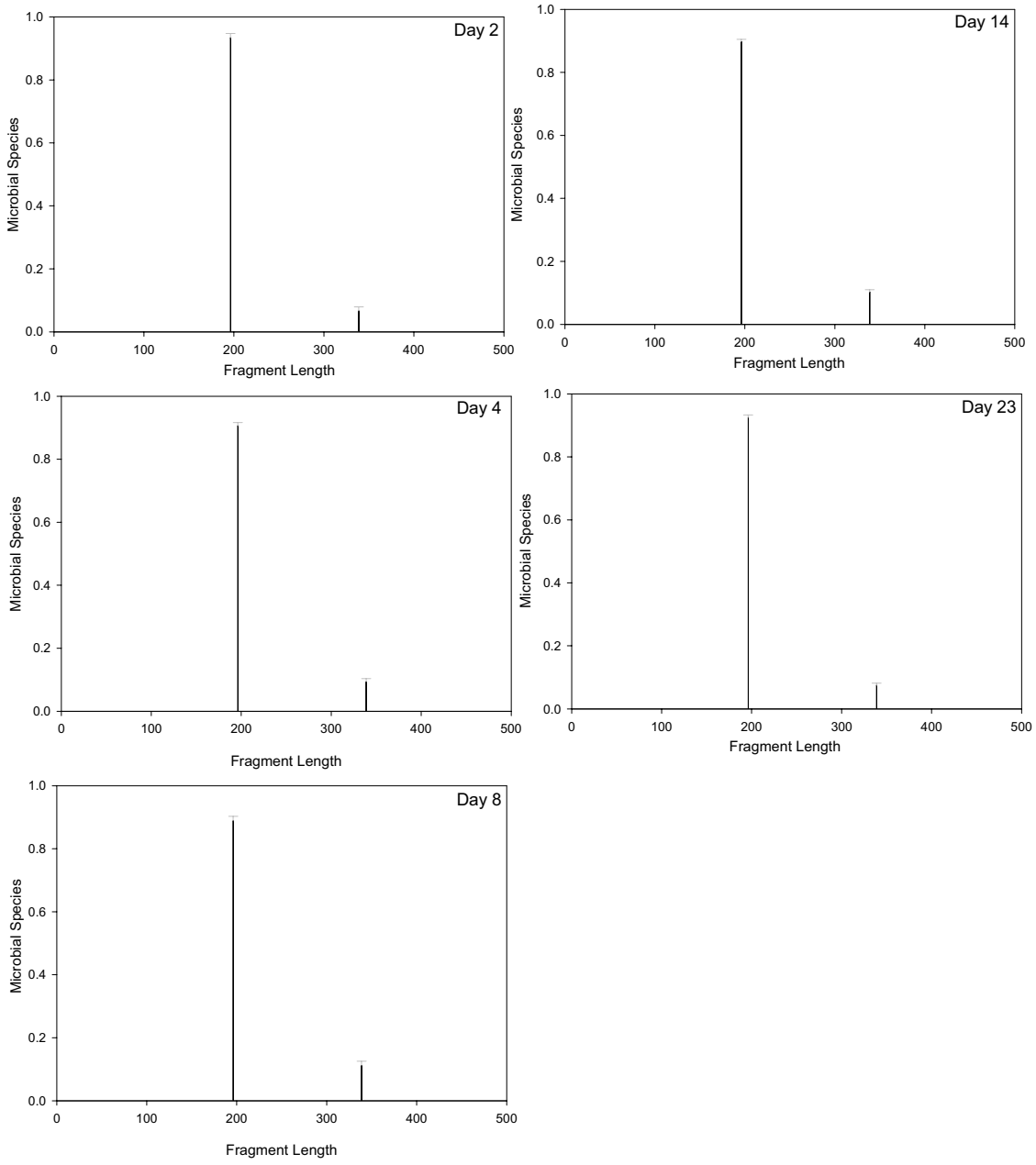

Figure A-53. Archaea T-RFLP dynamics generated as a result of averaging the response of communities following two whey powder injections (October 2004, January 2005).

A-4.5.2.3 Diversity of TAN-25 Bacteria Following Three Whey Powder Injections.

Table A-16 describes the diversity assessment of the samples collected for molecular T-RFLP analysis following the second and third whey powder injections (October 2004 and January 2005). The first column identifies the date the sample was collected; column 2 identifies the corresponding days after injection; column 3 identifies the number of T-RFs (taken as an indicator for the number of species); columns 4 through 6 identify the diversity parameters; and column 7 presents the similarity between the two T-RFLP profiles that correspond to the same point following a whey powder injection (i.e., Day 2). Diversity was evaluated by two measurements, Shannon-Weiner (Margalef 1958) and Simpsons indices (Simpsons 1948). The Shannon-Weiner index evaluates the diversity, accounting for species richness and proportion as well as the evenness of the community (Table A-16, E), while the Simpsons index evaluates diversity based on the abundance of the most common species. According to these data and based on the diversity indexes, diversity was generally lower on the Day 2 and Day 4 following whey powder injections when lactose fermentation was the greatest. Diversity was also lower on the last sampling day, Day 64, when the carbon source and secondary VFAs were depleted, and in general the conditions are not optimal with respect to microbial growth. These data are consistent with the conceptual model of lactose (or lactate) stimulating enrichment of fermenters and reducing the overall diversity of the community relative to time periods when lactose is not present.

Table A-16. Terminal restriction fragment length polymorphism diversity assessments at TAN-25 following whey powder injections in October and January 2005.

Date Sampled	Days after Lactate Injection	S (T-RFs)	Shannon-Wiener	Simpsons	E	Jaccard coefficient
10/12/2004	2	15	2.37	0.69	0.61	0.39
1/11/2005	2	10	1.52	0.47	0.46	
10/14/2004	4	16	2.92	0.80	0.73	0.59
1/13/2005	4	11	2.07	0.66	0.60	
10/19/2004	7	16	3.12	0.85	0.78	0.87
1/18/2005	7	12	2.62	0.80	0.73	
10/25/2004	14	28	3.53	0.87	0.74	0.70
1/24/2005	14	21	2.99	0.80	0.68	
11/1/2004	21	39	4.57	0.94	0.86	0.62
1/31/2005	21	29	3.94	0.91	0.81	
11/16/2004	35	39	4.33	0.92	0.82	0.37
2/15/2004	35	20	2.31	0.61	0.53	
12/14/2004	64	18	2.89	0.76	0.69	

The reproducibility of the T-RFLP method for both Bacteria and Archaea was assessed by determining the Jaccard coefficient for the composite T-RFLP profiles generated for comparable days following the second and third whey powder injections (Dunbar et al. 2001). Jaccard coefficients are based on binary variables of peak presence and are equal to the ratio of matching T-RFs to the total number of T-RFs present in the profiles being compared. The values range from 0 to 1, with a value of 1 meaning that all of the T-RFs are identical in the profiles being compared. The results following the two whey powder injections suggest that the T-RFLP profiles were similar during some sampling periods

following the injection (0.59 to 0.87, Days 4–21) but dissimilar for others, 0.39 on Day 2 and 0.37 on Day 35. These results are not unexpected as the utilization pathways and available electron donors (lactate versus lactose) have been altered. While microbial populations are dynamic and can respond to changes in local environments quickly, there is some time lag expected for transition from a community that utilizes one electron donor to another.

A-4.5.3 QPCR of Dehalococcoides

QPCR was performed in order to assess the number of 16S rRNA gene copies/L of TAN-25 groundwater. Figure A-54 illustrates the concentrations of *Dehalococcoides* present during the two rounds (March 2004 and May 2004) of lactate injections. The error bars represent the standard deviation of three replicate DNA extractions that were performed for each sampling point. In general, *Dehalococcoides* remained fairly stable (~10^8 to 10^9 gene copies/L of groundwater). A significant decline was observed after the Day 71 sampling event, with approximately 10^7 cells/L of groundwater detected.

Figure A-54 illustrates the concentrations of *Dehalococcoides* present following the two baseline sodium lactate injections and the October 2004 and January 2005 whey powder injections. The error bars represent the standard deviation of three replicate DNA extractions that were performed for each sampling point. Following the two whey powder injections *Dehalococcoides* were generally lower, ranging from (~10^5 to 10^8 gene copies/L of groundwater compared to values observed during the sodium lactate injection cycles. The lowest concentrations of *Dehalococcoides* were detected on the Day 22 or 23 sampling event following both whey powder injections. This suggests that the period of low pH may have a negative impact on this population (Figure A-55). Figure A-55 illustrates pH at TAN-25 and the corresponding numbers of *Dehalococcoides*. The Dehalococcoides response is time shifted, which is consistent with the limitations of the DNA-based QPCR method, which will detect DNA from cells that are inactive and/or dead. Therefore, there is a lag between when a cell actually dies, and when it is reflected in the DNA analysis. *Dehalococcoides* numbers rise after Day 22 or 23, after pH has fully recovered.

A-4.6 Quality Assurance

Samples were collected and analyzed during the AED optimization to comply with the quality assurance (QA) requirements specified in the current *Quality Assurance Project Plan for Waste Area Groups 1, 2, 3, 4, 5, 6, 7, 10, and Inactive Sites* (DOE-ID 2004b). Minimum external and internal QA frequencies and corrective actions were the same as those used for ISB groundwater monitoring (INEEL 2003a). The ISB Groundwater Monitoring Plan (INEEL 2003a) required screening level data with semi-annual definitive confirmation for VOCs, definitive level data for radionuclides, and screening level data for all other analytes. Three distinct sets of QA requirements are specified in the Groundwater Monitoring Plan for the three categories of analysis: (1) field laboratory analyses, (2) IRC laboratory analyses, and (3) off-site laboratory analyses. The results of the QA analyses for each laboratory are reported in their respective sections below, with details provided in Appendix C.

A-4.6.1 ISB Field Laboratory

Data generated by the ISB field laboratory are considered screening level data and are used as general indicators of changing geochemical conditions. The Groundwater Monitoring Plan (INEEL 2003a) requires analysis of field duplicates, field blanks, standards, and standard additions (matrix spikes). Acceptable precision and accuracy targets are included in TPR-166, “In Situ Bioremediation Field Laboratory Procedure.” Although QA samples are required to be collected and analyzed at a specified frequency, the associated targets for accuracy or precision are established as an internal quality check. Definitive data are not required for the ISB field laboratory tests.

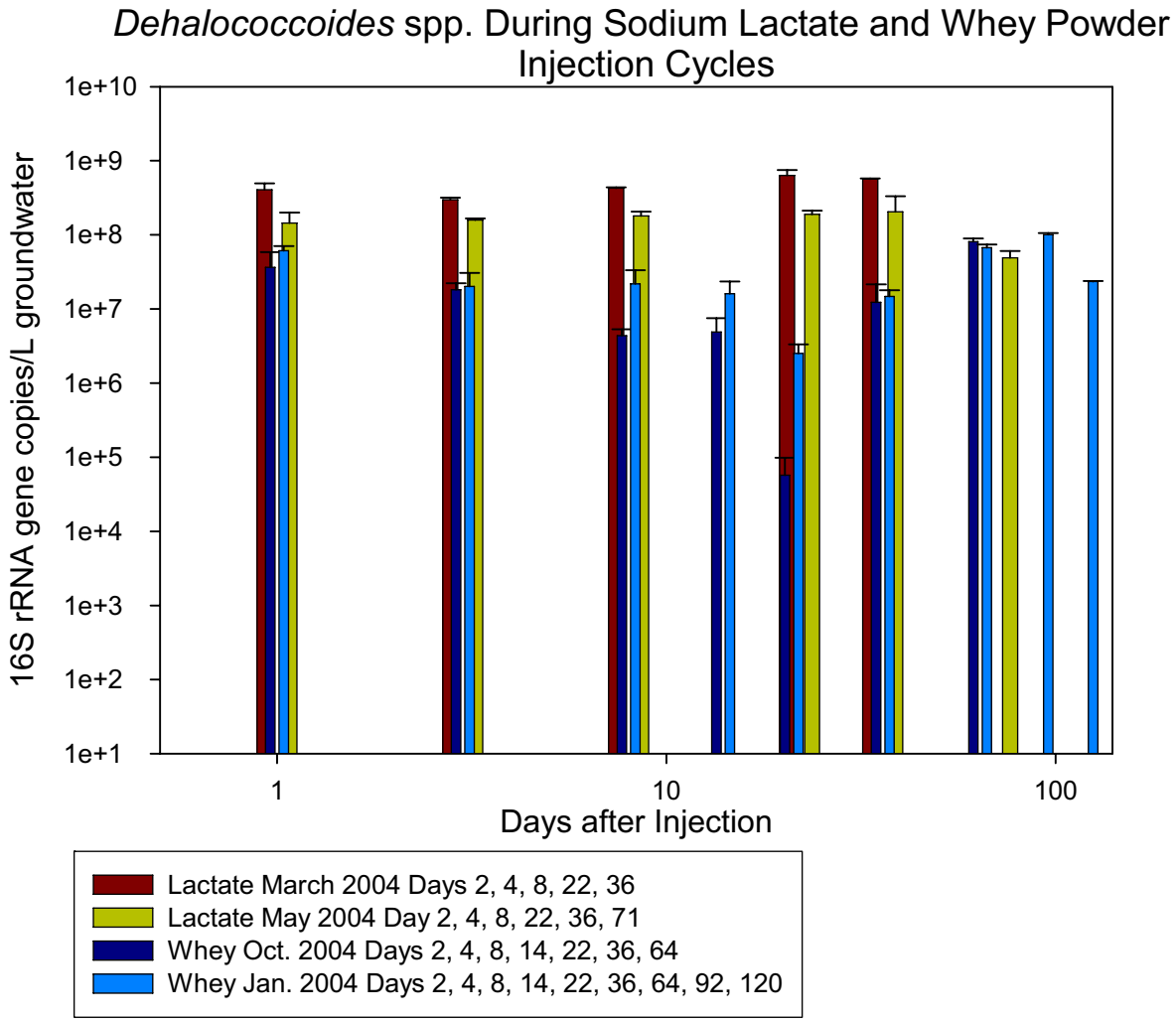

Figure A-54. *Dehalococcoides* in TAN-25 following sodium lactate and whey powder injections.

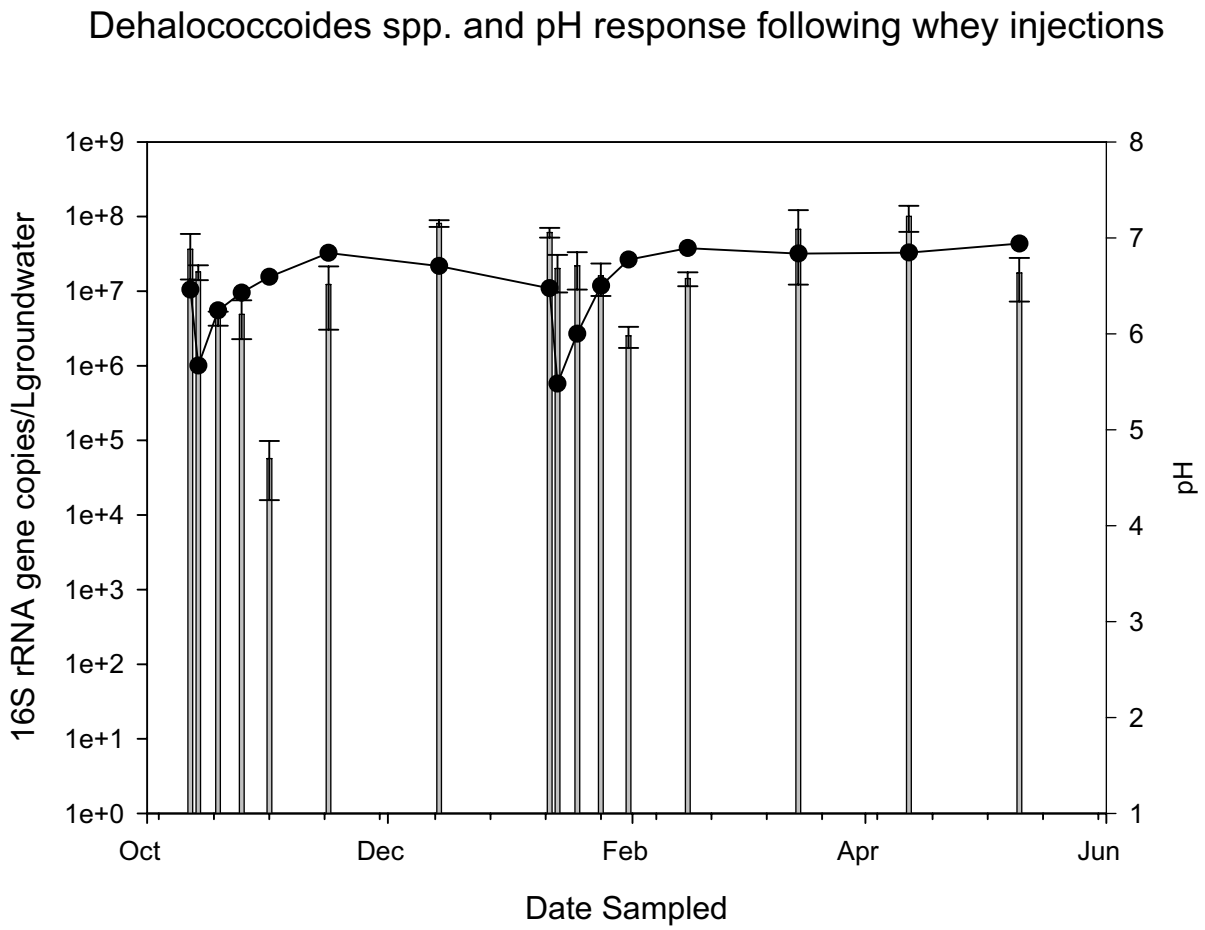

Figure A-55. *Dehalococcoides* and pH in TAN-25 following the second and third whey powder injections.

Geochemical parameters and nutrients were analyzed immediately after sample collection using Hach® field test kits. The results of these evaluations indicate that the field tests generally provide accurate measurements (Appendix C) with the exception of COD, for which corrective actions were taken. Field duplicate results indicate the precision of the field test kit analyses (Appendix C). The analyses established that the majority of RPDs were within range: alkalinity (38 of 38 duplicate results), ammonia (5 of 6 duplicate results), COD (37 of 48 duplicate results), iron (57 of 58 duplicate results), phosphate (5 of 7 duplicate results), and sulfate (24 of 27 duplicate results).

A-4.6.2 IRC Laboratory

Volatile organic compounds, dissolved gas, and electron donor constituents are analyzed at the IRC. These data are considered screening level data where rapid turn around times and economical analyses are an important consideration. The Groundwater Monitoring Plan requires analysis of field duplicates, blanks, and matrix spike/matrix spike duplicates (MS/MSDs), and requires the laboratory to perform initial and continuing calibration checks.

During the AED optimization, split samples from each well were analyzed by the off-site laboratory on a semi-annual basis to address the Groundwater Monitoring Plan requirement for independent verification of the IRC VOC results for the ISB sampling rounds only. With the exception of cis-DCE and VC, the majority of the VOC split samples had relative differences of less than 25%. The

results of the SPME analysis were both above and below the 8260B results, with no apparent bias. Details of the split sample analysis are presented in Appendix C.

A more definitive measure of accuracy of the IRC laboratory methods is provided by using performance evaluation (PE) samples. On a monthly basis, commercially-supplied, certified PE standards were included with the groundwater samples submitted to the IRC laboratory. Both high (>100 ppb) and low (<100 ppb) concentration standards were used to evaluate method accuracy in several concentration ranges. The results of the PE sampling program indicate that the SPME method used at the IRC is accurate for the contaminant of concern, TCE.

Precision of the VOC and dissolved gas data was evaluated by comparing results of duplicate samples. The RPD for TCE ranged from 1 to 13%, which met the TCE precision requirement of 14%. For all other VOC and dissolved gases, 88% of the duplicate samples had an RPD of <25%. Precision of the dissolved gas data using the new sampling method was also evaluated comparing the results of duplicate samples. Each dissolved gas sample was taken and analyzed in duplicate for each AED well. The RPDs calculated using the new sampling method for each AED well for ethene at TSF-05A, TSF-05B, TAN-25, TAN-31, and TAN-1859 ranged from 0.03 to 66%, 0.79 to 60%, 0 to 39%, 5.7 to 64%, and 2.6 to 46%, respectively. The RPD for methane at TSF-05A, TSF-05B, TAN-25, TAN-31, and TAN-1859 ranged from 0.66 to 35%, 1.1 to 81%, 0.78 to 26%, 0.37 to 57%, and 0.77 to 33%, respectively.

A-4.6.3 Off-Site Laboratories

For the ISB samples, semi-annual split samples are sent to off-site laboratories for definitive confirmation of VOC concentrations. Six of eight off-site TCE duplicate samples met the target RPD of 14%. For the remaining VOC analytes, the RPD ranged from 0 to 100%. Standard and matrix spike recoveries were evaluated as part of the Level A data validation. MS/MSD sample recoveries fell within range for all but one TCE analyses sent to an off-site laboratory. In addition to the laboratory prepared spikes, commercially prepared PE samples were also submitted to the off-site laboratory for VOC analysis in May 2004, November 2004, and June 2005. The samples represented both high (>100 µg/L) and low (<100 µg/L) VOC sample ranges. All the PE samples were within range for all analytes. Tritium and Sr-90 duplicate sample results ranged from 0 to 59%, with one outlying tritium result. QA results for radionuclide samples sent off-site are detailed in Appendix C.

A-4.7 Cost

Sodium lactate and whey powder costs for the AED optimization are presented in Table A-17. Unit costs represent the actual prices of the amendments used during AED optimization. Costs per injection and cost based on the number of injections performed during the AED optimization are also shown in Table A-17.

Table A-17. Alternate electron donor optimization electron donor costs.

Electron Donor	Unit Cost	Cost Per Injection	Number of Injections	Amendment Cost
Whey Powder	$0.275/lb	$2,750	3	$8,250
Sodium Lactate (60% solution)	$0.79/lb ($8.77/gal)	$11,700	2	$23,400

A-5. DISCUSSION

This section discusses the results of activities performed during the AED optimization and includes a comparison of results following sodium lactate injections to results following whey powder injections. Section A-5.1 compares distribution, degradation, and utilization of both sodium lactate and whey powder following the electron donor injections. Comparison of geochemical conditions is presented in Section A-5.2. Section A-5.3 compares the dechlorination efficiency and enhanced dissolution resulting from ARD following both sodium lactate and whey powder injections. Finally, Section A-5.4 compares cost.

A-5.1 Comparison of Electron Donor Distribution, Degradation, and Utilization

Injection of electron donor creates a biologically active area within the residual source area and results in degradation of TCE to below MCLs in groundwater. Ideally, contaminants are degraded within the biologically active area preventing the flux of contaminants to downgradient and crossgradient wells. However, previous injections into TSF-05 and TAN-1859 have failed to reach the entire residual source area, as indicated by continued flux to TAN-28 (downgradient) and TAN-1860 and TAN-1861 (crossgradient). Therefore, one important comparison to be made between electron donors is the magnitude of the distribution of the electron donor throughout source area.

Overall, both amendments were distributed radially approximately 92 ft, as evidenced by increased COD concentrations in TAN-25, TAN-31, and TAN-1859. However, when the data are normalized to the COD concentration measured on Day 2 after injection at TSF-05A and TSF-05B, there is a 20% increase in COD distributed to TAN-31 with whey powder injections as compared to sodium lactate. There was no significant change in the relative COD concentrations at TAN-25 between whey powder and sodium lactate injections. Normalizing the COD concentrations in TAN-25 and TAN-31 with the concentrations in TSF-05 allows us to directly compare the variable volume injections considered in this AED optimization. The normalized COD concentrations are presented in Figure A-56. These normalized COD concentrations indicate that more electron donor was distributed to TAN-31 with whey powder injections as compared to sodium lactate injections during the AED optimization.

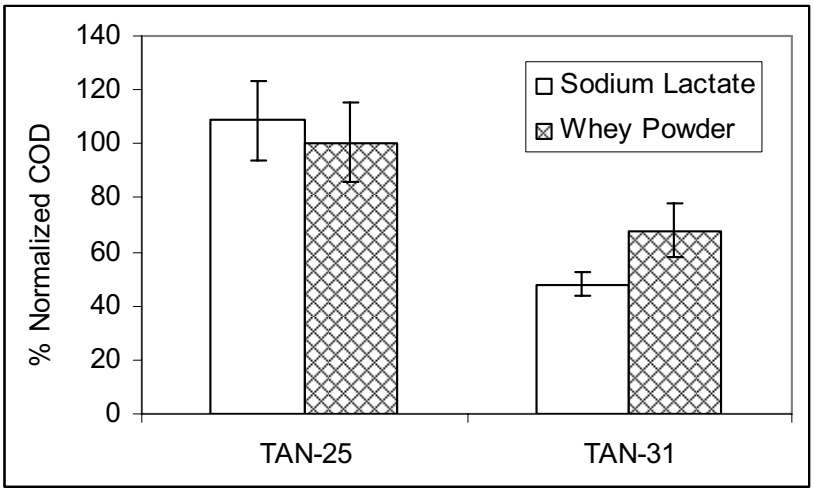

Figure A-56. Distribution of electron donor at TAN-25 and TAN-31 on Day 2 following injections. Chemical oxygen demand concentrations are normalized to chemical oxygen demand on Day 2 at TSF-05A and TSF-05B.

A-5.1.1 Comparison of Distribution and Degradation

As shown in Section A-4, there are multiple pathways for the degradation of sodium lactate and whey powder or lactose after injection of electron donors. The primary substrate injected (e.g., whey powder) is degraded into secondary fermentation products including VFAs and hydrogen, which ultimately is the source of electron donor for the TCE degrading community. Acetate, butyrate, and propionate were the primary VFAs observed following injections during the AED optimization. However, there were distinct differences in the ratio of these VFAs produced during whey powder and lactate degradation. For instance, if the maximum concentration of each VFA observed (regardless of the time point) was normalized on a molar basis to the estimated initial concentration of lactate or lactose injected into the aquifer (calculated from first order decay rates), then there were measurable differences in the ratio of acetate, propionate, and butyrate. Normalization of the observed VFA concentrations allows direct comparison of the formation of these products between variable volume and electron donor injections. Percent normalized concentrations of VFAs are presented in Figure A-57. The normalized VFA concentrations indicate that during whey powder degradation, significantly more acetate and propionate are produced in TSF-05B, TAN-25, and TAN-31. Additionally, the results indicate that of the VFAs monitored, butyrate is a major product of the degradation of whey powder as compared to lactate degradation.

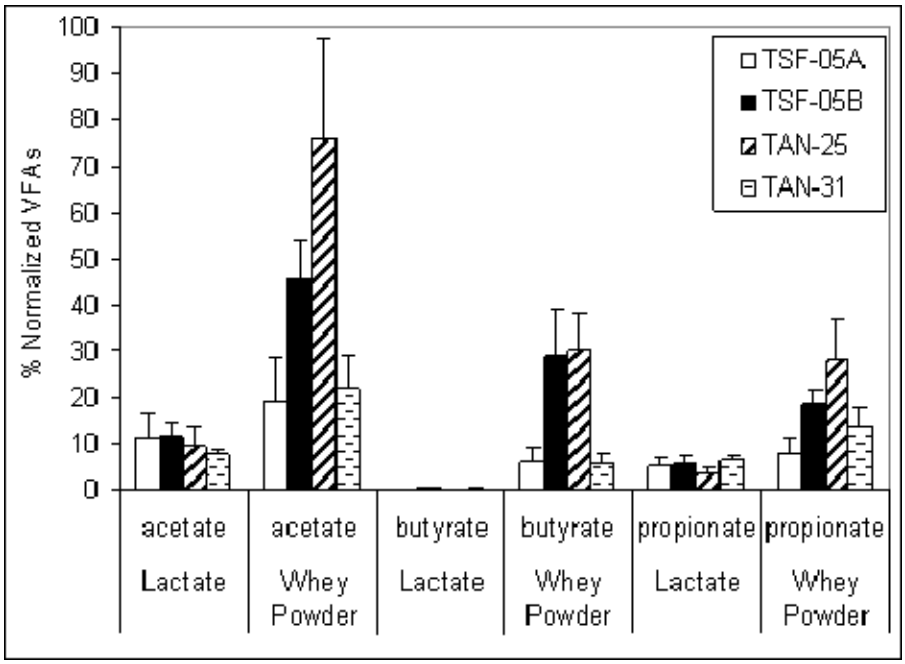

Figure A-57. Comparison of the production of volatile fatty acids, as shown by percent normalization of volatile fatty acids in the alternate electron donor wells, between lactate and whey powder.

A-5.1.2 Comparison of Utilization

As reported in Section A-3, the primary substrate of whey powder injections, lactose, was fermented at a substantially higher rate (factor of 2–6 times higher utilization rate coefficient) at TSF-05A, TAN-25 and TAN-31, and was comparable at TSF-05B than sodium lactate. In contrast, evaluated depletion of all substrates, including secondary fermentation products, is evaluated using the COD degradation rate constants. The COD values were higher (approximately 50% faster) in TSF-05B following whey powder injections as compared to sodium lactate injections, but were comparable at

TSF-05A, TAN-25, and TAN-31. The higher rate of lactose fermentation is likely responsible for the generation of high concentrations of acid over a relatively short period, and the subsequent drop in pH observed following whey powder injections. The degradation rates following whey powder injections combined with the similarity in COD degradation rates between electron donors suggests that the parent compound lactose is rapidly depleted in the groundwater (by Day 8–10 on average), compared to Day 21 for lactate, while the daughter products (i.e., acetate, butyrate and propionate) remain in the system for approximately the same time for both injection amendments.

A-5.2 Comparison of Geochemical Conditions

Monitoring geochemical conditions, specifically redox parameters and biological activity indicators, provides an indication of the relative size of the biologically active area and can provide a quick indication of the relative health of the system. Redox conditions in the area of the AED optimization have remained methanogenic throughout ISB operations, as indicated by complete sulfate reduction, elevated ferrous iron concentrations, and high concentrations of methane. Few differences in redox conditions were observed following the transition to whey injections. One notable exception was spikes in sulfate on Days 2 and 4. These spikes, which are temporary, are attributed to the presence of sulfate in whey powder. Therefore, the presence of sulfate in whey powder does not affect overall dechlorination performance.

Alkalinity and pH are two important indicators of overall biological activity. Alkalinity and pH were similar throughout the baseline sodium lactate injections. Significant decreases in pH were observed from Day 2 through Days 8–10 following whey injections. Typical pH values ranged from 5.5 to 6.0, following the rapid fermentation of lactose. In all cases, the lowest pH value was observed on Days 8–10, which correlates with complete degradation of lactose. Additionally, the magnitude of the pH drop at a particular location correlated with the concentration of lactose in that those locations that received the highest concentrations of lactose also saw the largest drop in pH. At the same time, methane and ethene concentrations directly following a whey powder injection were lower than observed following a sodium lactate injection, indicating that the low pH might negatively impact both methanogenesis and ARD, although the generation of lots of foam and degassing during sampling may have also contributed to the drops observed. A decline in the total concentration of *Dehalococcoides*, as indicated by QPCR, also suggests that this population is negatively impacted by the low pH. These drops in pH were temporary, rebounding to pre-injection levels by Days 15 to 22 or 23. In addition, dechlorination efficiency remained high, as evidenced by rapid degradation of TCE and its associated degradation products by the end of a 36-day injection cycle.

A-5.3 Anaerobic Reductive Dechlorination

Anaerobic reductive dechlorination is the key degradation mechanism contributing to the success of ISB operations at TAN. Comparing both the dechlorination efficiency and enhanced dissolution that occurs following whey powder injections compared to sodium lactate injections was a key decision criteria in assessing the performance of each.

A-5.3.1 Comparison of Dechlorination Efficiency

Figure A-58 illustrates the total molar concentrations of TCE, cis-DCE, VC, and ethene measured during the AED sampling events. The error bars represent one standard deviation for n=2 sampling events for sodium lactate points, except for Day 64–65 or 71–73, which only had one time point, and n=3 sampling events for whey powder, except for Day 15 and Day 64–65, which only had two time points. In general, the total molar concentration of these products was significantly higher following whey powder injections compared to the sodium lactate injections for the different time points during the injection cycle

especially at the times of Day 8–10, Day 22 or 23, Day 36–38, and Day 64–65 time points. Overall, these data suggest that more mass is being degraded over an injection cycle following whey powder injections compared with sodium lactate injections (see Section A-5.3.3 for further discussion).

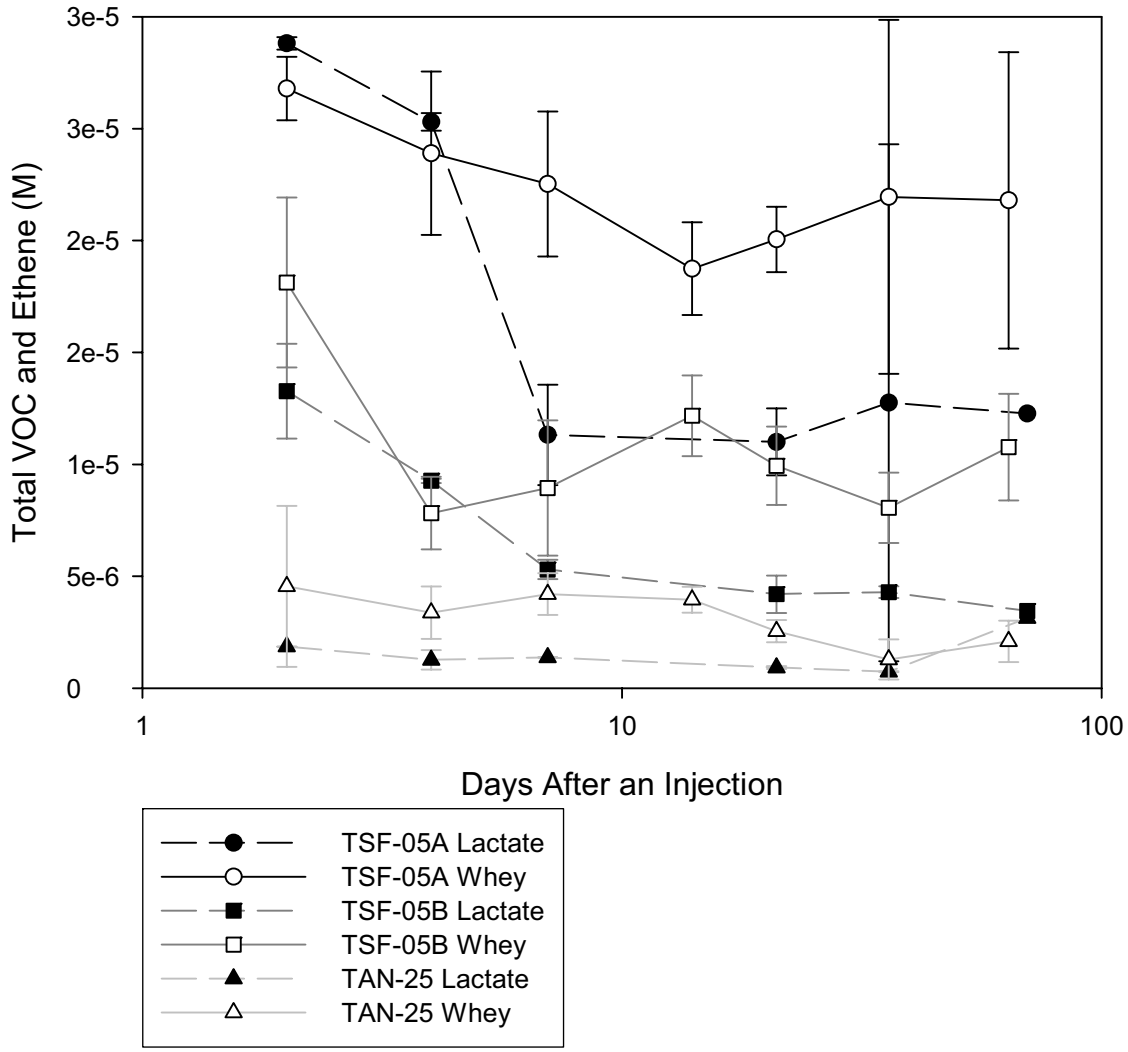

Figure A-58. Comparison of the average total molar concentrations of TCE, cis-DCE, VC, and ethene of sodium lactate and whey powder injection cycles.

Figures A-59, A-60, and A-61 illustrate the average total molar concentrations of TCE, cis-DCE, and VC during the two sodium lactate injection cycles, and the three whey powder injection cycles for TSF-05A, TSF-05B, and TAN-25. These figures show that substantially more total molar mass of contaminants present as parent compounds directly after a whey powder injection compared to a sodium lactate injection. These data may be conservative for Days 2, 4, and 8–10 following whey powder injections due to difficulties sampling, because of the high foam content of the sampled groundwater at these locations. Initially, the presence of greater total mass of contaminants (Figure A-58), along with higher concentrations of parent compounds (Figures A-26 through A-29) by Day 8–10 suggests that more contaminant mass is liberated following a whey powder injection compared to that observed following the sodium lactate injection in and around TSF-05 and TAN-25.

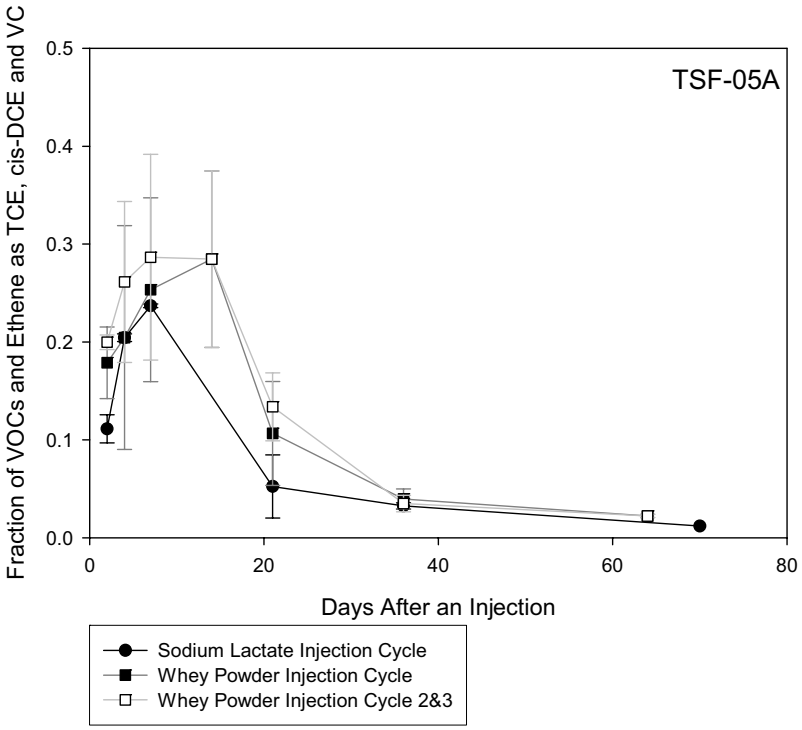

Figure A-59. Comparison of fraction of total molar concentrations of TCE, cis-DCE, and VC during sodium lactate, whey powder injection cycles 1–3, and whey powder injection cycles 2&3 at TSF-05A.

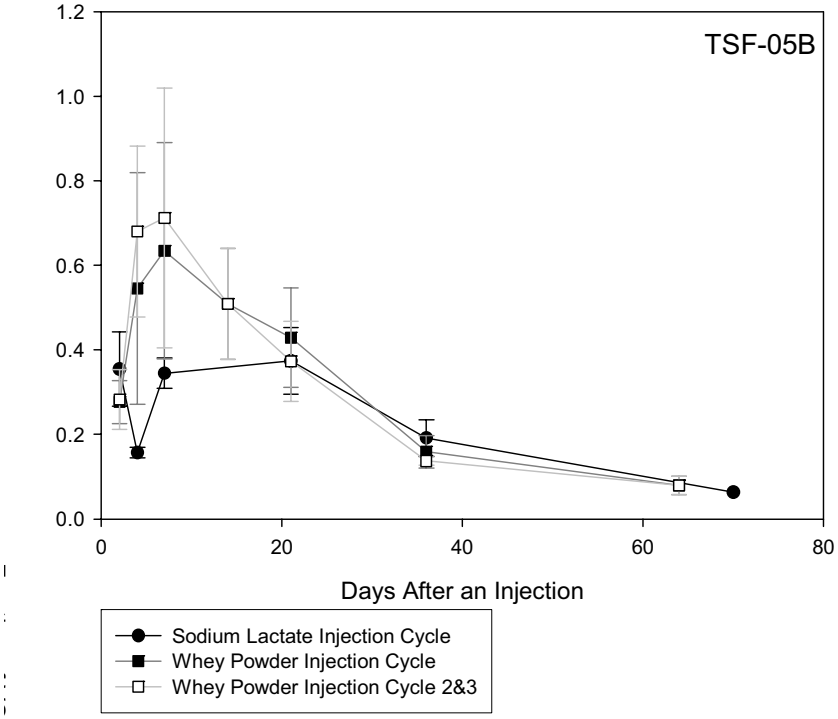

Figure A-60. Comparison of fraction of total molar concentrations of TCE, cis-DCE, and VC during sodium lactate, whey powder injection cycles 1-3, and whey powder injection cycles 2&3 at TSF-05B.

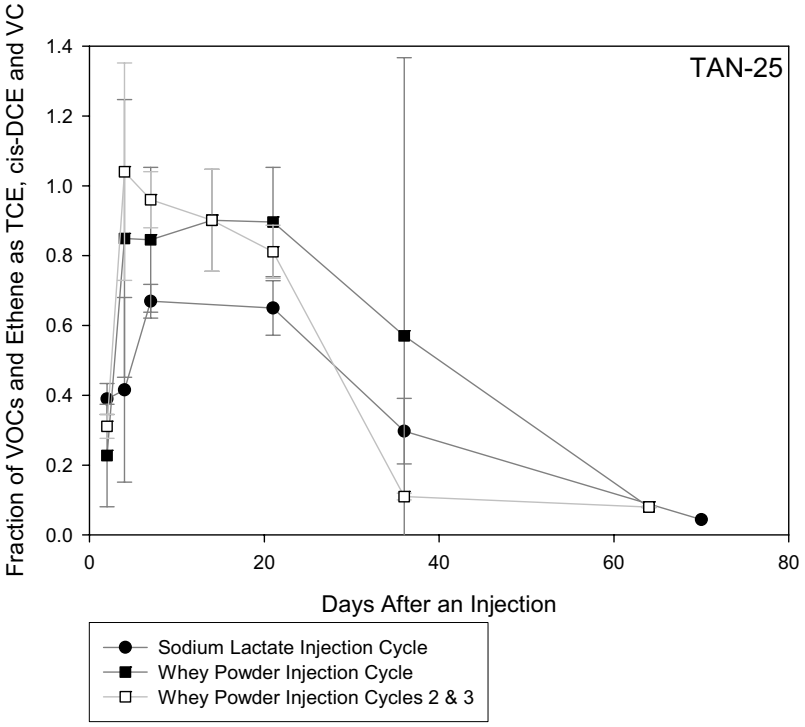

Figure A-61. Comparison of fraction of total molar concentrations of TCE, cis-DCE, and VC during sodium lactate, whey powder injection cycles 1–3, and whey powder injection cycles 2 & 3 at TAN-25.

The fraction of total chlorinated ethenes and ethene present as TCE, cis-DCE, and VC (Figures A-59 through A-61), however, suggest that a greater fraction of the total chlorinated ethenes and ethene are present as parent compounds at Day 8–10 at TSF-05B and TAN-25 following a whey powder injections compared to the sodium lactate injections. This may be due in part to the greater total concentrations of parent compounds liberated following the whey powder injections. By Day 22 or 23, however, the fraction of parent compound is statistically similar at TSF-05 following the whey powder compared to the sodium lactate injections. This suggests that dechlorination efficiency is greater following whey powder injections than the lactate injections at these locations as a greater reduction in the fraction of parent compounds is observed between the Day 8–10 and Day 22 or 23 sampling events. At TAN-25, however, the fraction of parent compound is statistically higher at Day 22 or 23 following the whey powder injections compared to the sodium lactate injections. At TAN-25, the Day 36–38 sampling event also showed statistically higher fraction of parent compound present following the whey powder injections compared to following sodium lactate injections. This was due, however, to an order of magnitude higher concentration of total parent compound observed following the first whey powder injection compared to the second and third whey powder injections. Therefore, if only the second and third whey powder injections are averaged, then the fraction of parent compound at Day 36–38 is statistically lower following whey powder injection than the sodium lactate. This suggests that dechlorination efficiency improved at this location following the second and third whey powder injections compared to what was observed following the first whey powder injection. The Day 36–38 fraction of TCE, cis-DCE, and VC also dramatically declined at TSF-05 following both whey powder and sodium lactate injections. There was also no statistically significant difference between the trends observed whey all three whey powder injection cycles were averaged compared to when only the second and third whey powder injection cycles were averaged. Overall, these data suggest that whey powder is as effective at degrading parent compounds as sodium lactate. In fact, although more parent compound was liberated following the whey powder injections, the fractions of parent compounds was comparable over an

injection cycle to sodium lactate, suggesting that whey powder may have a greater overall dechlorination efficiency than sodium lactate (See Section A-5.3.2).

A-5.3.2 Comparison of Enhanced Dissolution

The whey powder injections into TSF-05 also resulted in significant increases in parent compound directly after the injection followed by efficient conversion of the parent compound to ethene (Figures A-26, A-27 in Section A-4.3.1). The magnitude of the increases, however, was greater than those observed during the baseline sodium lactate injections (Figures A-62 through A-64) by Day 8–10. The increased enhanced dissolution effects can be seen by significantly higher spikes in both total averaged TCE, cis-DCE, VC, and ethene concentrations, and total averaged TCE, cis-DCE, and VC observed on Days 8–10 in TSF-05A, TSF-05B, and TAN-25 (Figures A-62 to A-64).

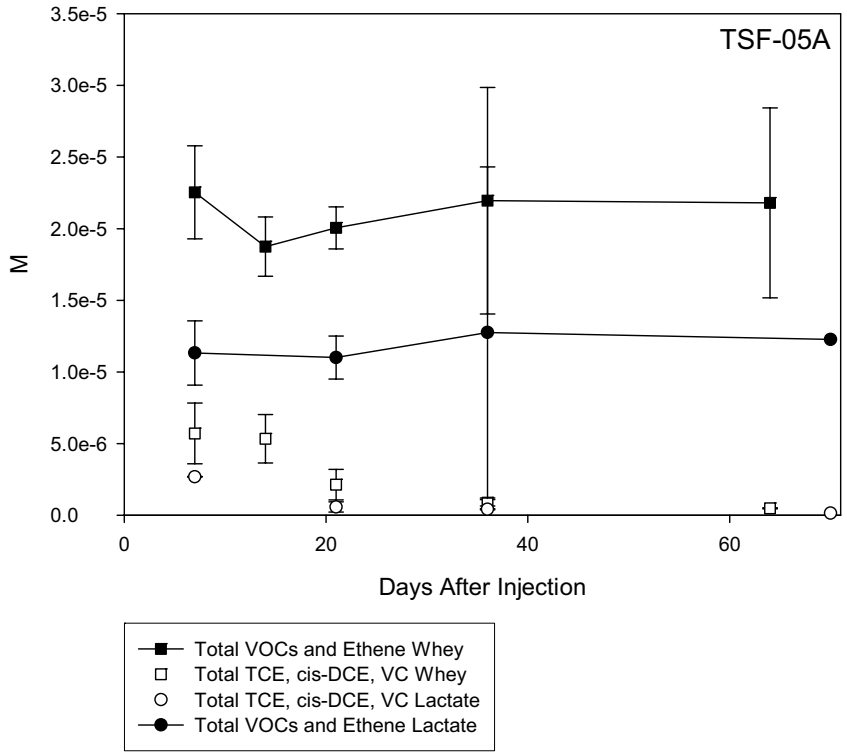

Figure A-62. Average total TCE, cis-DCE, VC, and ethene concentration compared to total TCE, cis-DCE, VC, concentration at TSF-05A one week following injections.

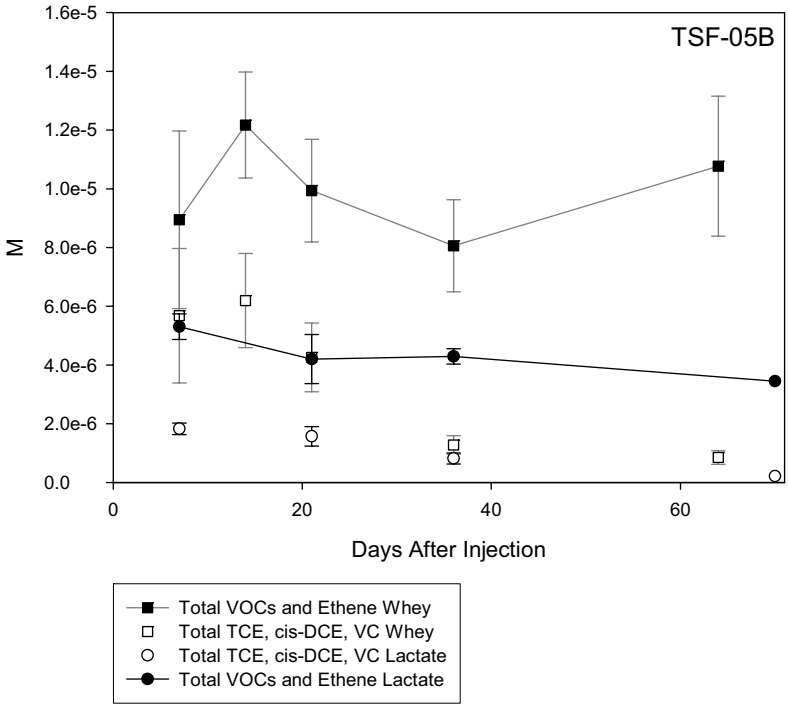

Figure A-63. Average total TCE, cis-DCE, VC, and ethene concentration compared to total TCE, cis-DCE, VC, concentration at TSF-05B one week following injections.

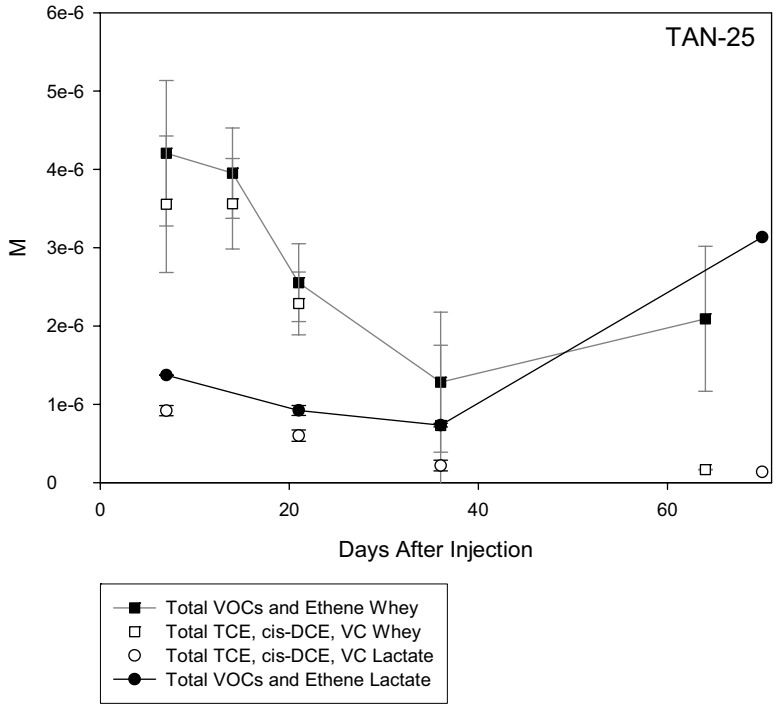

Figure A-64. Average total TCE, cis-DCE, VC, and ethene concentration compared to total TCE, cis-DCE, VC, concentration at TAN-25 one week following injections.

The total concentrations of VOCs approximately 1 week following each injection were evaluated at TSF-05A, TSF-05B, and TAN-25. Figures A-62 through A-64 present the results. Figure A-62 shows that average total VOC and ethene concentrations at TSF-05A were slightly higher 1 week following the whey powder injections as compared to the baseline sodium lactate injections. The average whey powder concentration following the three injections was 11% higher than the average sodium lactate concentration following two injections. Figure A-63 shows that average total VOC concentrations at TSF-05B were higher 1 week following the whey powder injections as compared to the baseline sodium lactate injections. The average whey powder concentration following the three injections was 27% higher than the average sodium lactate concentration following two injections. Figure A-64 shows that average total VOC concentrations at TAN-25 were significantly higher 1 week following injections for all the whey powder injections as compared to the baseline sodium lactate injections. The average whey powder concentration following the three injections was 136% higher than the average sodium lactate concentration following two injections. In addition, the total average molar concentration of TCE, cis-DCE, VC and ethene was higher throughout the injection cycle to Day 36–38 at TSF-05 and TAN-25. The higher total concentrations of contaminants following injections, and the higher total concentrations of contaminants and reductive daughter product following whey powder injections suggests that whey powder is a better electron donor for facilitating greater contaminant mass removal over an injection cycle than sodium lactate. This suggests that over the long term, more contaminant mass will be removed faster, thus reducing the overall timeframe of the ISB remedy at TAN.

A-5.4 Cost

Cost comparisons between sodium lactate and whey powder are discussed in the section. A direct cost comparison between amendments is discussed in Section A-4.6.1, and a comparison of cost based ARD efficiency is discussed in Section A-4.6.2.

A-5.4.1 Comparisons of Cost per Injection

A comparison of cost per injection for sodium lactate and whey powder during the AED optimization is presented in Table A-18. Since both sodium lactate and whey powder injections use comparable manpower and take approximately the same amount of time, labor costs are assumed to be the same for each type of injection and are not included in this comparison. Costs used in Table A-18 represent the actual delivered price of sodium lactate and whey powder used during the AED optimization. However, since whey powder is traded as a commodity, its price can fluctuate based on demand; therefore, a worst case scenario price of $0.35/lb for whey powder is shown.

Table A-18. Comparison of cost per injection for sodium lactate and whey powder.

Electron Donor	Unit Cost	Cost Per Injection	Injection Frequency (Annually)	Annual Cost	Annual Cost Saving
Whey Powder	$0.275 per lb[a]	$2,750	6	$16,500	$53,700
	$0.35 per lb[b]	$3,500	6	$21,000	$49,200
Sodium Lactate (60% solution)	$0.79 per lb ($8.77 per gal)	$11,700	6	$70,200	NA

a. Actual cost of delivered whey powder used for the AED optimization.
b. Due to fluctuations in the price of whey powder, this price is being presented as a worst case scenario.

Based on the injection strategy used during the AED optimization, the price of whey powder would have to increase to $1.17/lb in order for the cost per injection to equal that of sodium lactate. As shown in Table A-18, the lower cost of whey powder results in an annual cost savings between $49,200 and $53,700. The injection frequency for this cost comparison is for six injections per year for both sodium lactate and whey powder. This injection frequency is based on the sodium lactate injection strategy used prior to the AED optimization and is used for direct comparison of the amendments.

A-5.4.2 Comparisons of Cost based on ARD Efficiency

Cost of electron donor was compared based on ARD efficiency (i.e., TCE degraded over time). The total molar concentrations of VOCs degraded were calculated by taking the sum of the total molar concentrations of the VOCs at TSF-05A, TSF-05B, TAN-25, and TAN-31 over the time between injections (Table A-19). Since the days between injections varied during the AED optimization, the amendment injection cost per molar concentration of VOCs degraded over time were compared between injections using the concentration of VOCs degraded during the first 36 to 38 days after each injection (sampling to Days 36–38 days is the shortest duration between injections during the AED optimization).

Table A-19. Cost calculations based on anaerobic reductive dechlorination efficiency.

Injection Date	Electron Donor	Injection Cost ($)	Total (Mole/L)*Day VOCs Degraded	Days Between Injections	Cost Per Injection/(Mole/L)*Day (Over First 36 Days)
TSF-05A					
March 15, 2004	Sodium Lactate	11,700	2.40E-04	36	4.88E+07
May 10, 2004	Sodium Lactate	11,700	5.99E-04	71	5.05E+07
August 16, 2004	Whey Powder	2,750	3.55E-04	36	7.75E+06
October 11, 2004	Whey Powder	2,750	7.63E-04	64	7.94E+06
January 10, 2005	Whey Powder	2,750	1.76E-03	156	7.25E+06
TSF-05B					
March 15, 2004	Sodium Lactate	11,700	1.98E-04	36	5.91E+07
May 10, 2004	Sodium Lactate	11,700	3.13E-04	71	6.73E+07
August 16, 2004	Whey Powder	2,750	3.46E-04	36	7.95E+06
October 11, 2004	Whey Powder	2,750	6.23E-04	64	8.79E+06
January 10, 2005	Whey Powder	2,750	1.78E-03	156	7.65E+06
TAN-25					
March 15, 2004	Sodium Lactate	11,700	3.66E-05	36	3.20E+08
May 10, 2004	Sodium Lactate	11,700	1.06E-04	71	3.08E+08
August 16, 2004	Whey Powder	2,750	1.02E-04	36	2.71E+07
October 11, 2004	Whey Powder	2,750	1.43E-04	64	2.99E+07
January 10, 2005	Whey Powder	2,750	3.96E-04	156	2.45E+07

Table A-19. (continued).

Injection Date	Electron Donor	Injection Cost ($)	Total (Mole/L)*Day VOCs Degraded	Days Between Injections	Cost Per Injection/(Mole/L)*Day (Over First 36 Days)
TAN-31					
March 15, 2004	Sodium Lactate	11,700	1.42E-05	36	8.23E+08
May 10, 2004	Sodium Lactate	11,700	5.29E-05	71	4.14E+08
August 16, 2004	Whey Powder	2,750	1.80E-05	36	1.53E+08
October 11, 2004	Whey Powder	2,750	2.69E-05	64	1.24E+08
January 10, 2005	Whey Powder	2,750	7.17E-05	156	8.95E+07

Table A-20 presents the average costs based on ARD efficiency from the two sodium lactate and three whey powder injections at TSF-05A, TSF-05B, TAN-25, and TAN-31. The average costs based on ARD efficiency show that whey powder provides a cost savings of between 5.10 to 11.60 times that of sodium lactate at these four locations.

Table A-20. Average cost calculations based on anaerobic reductive dechlorination efficiency.

Monitoring Location	Electron Donor	Average Cost Per Injection/(Mole/L)Day (Over First 36 Days)	Cost Saving of Whey Over Lactate
TSF-05A	Sodium Lactate	4.96E07	NA[a]
	Whey	7.65E06 (std.dev.=3.56E05)	**6.50**
TSF-05B	Sodium Lactate	6.32E07	NA
	Whey	8.13E06 (std.dev.=5.92E05)	**7.80**
TAN-25	Sodium Lactate	3.14E08	NA
	Whey	2.72E07 (std.dev.=2.67E06)	**11.60**
TAN-31	Sodium Lactate	6.19E08	NA
	Whey	1.22E08 (std.dev.=3.16E07)	**5.10**

a. NA = Not Applicable

A-6. CONCLUSIONS

The AED Optimization Plan (Harris and Hall 2004) identified decision inputs to be used when comparing the effectiveness of sodium lactate and whey powder based on the AED optimization results. Comparisons of the decision inputs are summarized in Table A-21.

Table A-21. Comparison results for sodium lactate and whey powder injections.

Decision Input	Sodium Lactate	Whey Powder
Electron Donor Distribution	Cannot be effectively distributed at concentrations greater than 6% nominal concentration as a result of density driven flow (INEEL 2000).	Can be effectively distributed at a 10% w/w concentration. Comparable volumes of a 10% w/w whey powder solution distributed higher concentrations of electron donor than 6% sodium lactate solution.
Electron Donor Utilization	Lower utilization rate of primary substrate; overall shorter longevity of secondary degradation products.	Higher utilization rate of primary substrate; overall greater longevity of secondary degradation products.
Geochemistry Parameters	Maintains methanogenic conditions.	Maintains methanogenic conditions. Decreases in pH observed following injections; however, pH rebounds to pre-injection levels within 2 to 3 weeks.
Anaerobic Reductive Dechlorination	Maintains complete dechlorination of dissolved TCE to ethene.	
Dissolution of TCE from the Residual Source	TCE dissolution from residual source.	Greater concentration of TCE dissolved and degraded from residual source over an injection cycle compared to sodium lactate.
Radionuclide Concentrations	Sr-90 concentrations increase following each injection; however, concentrations return to pre-injection concentrations.	Greater increased in Sr-90 concentrations were observed following sodium lactate injections. Higher concentrations of Sr-90 are correlated with reductions in pH; however, when pH rebounds, Sr-90 concentrations return to pre-injection concentrations.
Microbial Community Health	*Dehalococcoides* present in higher concentrations; higher population diversity; similar number of active organisms; supports efficient ARD.	*Dehalococcoides* present in lower concentrations; lower population diversity; similar number of active organisms; supports efficient ARD.
Cost	During the AED optimization: • Unit cost = \$0.79/lb • Cost per injection = \$11,700.	During the AED optimization: • Unit cost = \$0.275/lb • Cost per injection = \$2,750. The use of whey powder as an electron donor at TAN will result in a cost savings of \$8,950 per injection.

A decision matrix (Table A-22) was developed in the AED Optimization Plan (Harris and Hall 2004) to aid in identifying whether whey powder should be recommended as an AED. The decision matrix uses the cost and the effectiveness of whey powder injections as the criteria. The results of the AED optimization identified that the cost of whey powder injections was less than sodium lactate and that the effectiveness of whey powder injections was more than sodium lactate during the AED optimization. Therefore, as highlighted in Table A-22, the decision to recommend whey powder for future injections at TAN is conclusive.

Table A-22. Decision matrix for recommendation of whey powder as an alternate electron donor.

Cost of Whey Powder Injections (More than/less than/same as sodium lactate)	Effectiveness of Whey Powder Injections (More than/less than/same as sodium lactate)	Decision (Recommend AED = Yes Not recommend AED = No)
More	More	Decision will be based on data
More	Less	No
Less	**More**	**Yes**
Less	Less	No
Same	More	Yes
Same	Less	No
More	Same	No
Less	Same	Yes
Same	Same	No

A-7. RECOMMENDATIONS

Based on the conclusions of the AED optimization, whey powder was recommended as the electron donor for future ISB injections based on:

- High concentrations of whey powder were effectively distributed over a large area resulting in efficient ARD of TCE to ethene.
- The whey-stimulated microbial community, although significantly different from the lactate-stimulated community, support efficient ARD.
- Enhanced dissolution of TCE from the residual source into the aqueous phase was observed to a greater extent during a whey powder injection cycle compared to a sodium lactate injection cycle resulting in a greater rate of contaminant mass removal over time, and a reduction in the remedial timeframe.
- Cost per injection using whey powder is significantly less than using sodium lactate.

A-8. REFERENCES

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Appendix A

Sampling and Analysis Plan Tables

Sampling and Analysis Plan Table for Chemical and Radiological Analysis

02/10/2006 07:13 AM

Plan Table Number: INITIAL_OCT04

SAP Number: INEEL/EXT-2002-00779

Sampler: Carroll, R. E.

Date: 10/11/2004 Plan Table Revision: 1.0 Project: OU 1-07B ISB RA GWM - INITIAL MONTHLY 10/04 (PM) & AED Project Manager: NELSON, L. O.

SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																				
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
										A1	3A	C5	Y4	EG	F6	R5	MB	1N	RB	R8	VL	VM							
RAA450	REG	GROUND WATER	GRAB		10/18/2004	TAN	MONITORING WELL	TSF-05A (71)	235	1	1	1	1	1		1		1		1	1								
RAA451	REG	GROUND WATER	GRAB		10/18/2004	TAN	MONITORING WELL	TSF-05B (71)	270	1	1	1	1	1		1		1		1	1								
RAA452	REG/QC	GROUND WATER	DUP		10/18/2004	TAN	MONITORING WELL	TAN-25 (1117)	218	2	2	2	2	2		1	1	2	2	2	2								
RAA453	REG	GROUND WATER	GRAB		10/18/2004	TAN	MONITORING WELL	TAN-26 (1118)	389	1	1	1		1		1		1		1		1							
RAA454	REG/QC	GROUND WATER	DUP		10/18/2004	TAN	MONITORING WELL	TAN-27 (1009)	235	2	2	2		2				2		2	2								
RAA455	REG/QC	GROUND WATER	DUP		10/18/2004	TAN	MONITORING WELL	TAN-28 (1008)	240	2	2	2		2				2		2	2								
RAA456	REG	GROUND WATER	GRAB		10/18/2004	TAN	MONITORING WELL	TAN-29 (1010)	253	1	1	1		1	1			1		1		1							
RAA457	REG	GROUND WATER	GRAB		10/18/2004	TAN	MONITORING WELL	TAN-30A (1012)	313	1	1	1		1				1		1	1								
RAA458	REG	GROUND WATER	GRAB		10/18/2004	TAN	MONITORING WELL	TAN-31 (1219)	258	1	1	1	1	1		1		1		1	1								
RAA459	REG	GROUND WATER	GRAB		10/18/2004	TAN	MONITORING WELL	TAN-37A(1163)	240	1	1	1		1				1		1	1								
RAA460	REG	GROUND WATER	GRAB		10/18/2004	TAN	MONITORING WELL	TAN-37B (1163)	270	1	1	1		1				1		1	1								
RAA461	REG	GROUND WATER	GRAB		10/18/2004	TAN	MONITORING WELL	TAN-37C (1163)	375	1	1	1		1				1		1	1								
RAA462	REG	GROUND WATER	GRAB		10/18/2004	TAN	MONITORING WELL	TAN-10A (348)	233	1	1	1		1				1		1	1								
RAA463	REG	GROUND WATER	GRAB		10/18/2004	TAN	MONITORING WELL	TAN-D2 (339)	241	1	1	1		1				1		1	1								
RAA464	REG	GROUND WATER	GRAB		10/18/2004	TAN	MONITORING WELL	TAN-1859	250	1	1	1	1	1		1		1		1	1								

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

D - Double QC Volume T - Triple QC Volume

AT1: Alkalinity

AT2: Analysis Suite #1

AT3: Chemical Oxygen Demand

AT4: Dissolved Gases

AT5: Ethane/Ethene/Methane

AT6: Field Standard Addition - QC

AT7: Gamma Screen

AT8: Microbiological Analysis

AT9: Propionate/Butyrate/Acetate/Lactate - Filtered

AT10: Sr-90

AT11: Tritium

AT12: VOCs (CLP TAL)

AT13: VOCs (CLP TAL) - MS/MSD

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, Alkalinity, COD, and Field Standard Addition - QC

Samples will be sent to IRC except Tritium and Strontium-90 which will be shipped to an off-site lab

The third duplicate, field blank, and trip blank will only be collected if needed

AED Sampling is included on wells TSF-05A, TSF-05B, TSF-25, TSF-26, and TSF-31

Propionate/Butyrate/Acetate/Lactate - Lactate changed to Lactose

Dissolved Gases = Ethane/Ethene/Methane

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Plan Table Number: INITIAL_OCT04

SAP Number: INEEL/EXT-2002-00779 Sampler: Carroll, R. E.

Date: 10/11/2004 Plan Table Revision: 1.0 Project: OU 1-07B ISB RA GWM - INITIAL MONTHLY 10/04 (PM) & AED Project Manager: NELSON, L. O. SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																				
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	A1	3A	C5	Y4	EG	F6	R5	MB	1N	RB	R8	VL	VM							
RAA465	REG	GROUND WATER	GRAB		10/18/2004	TAN	MONITORING WELL	TAN-1860	269	1	1	1		1				1		1	1								
RAA466	REG	GROUND WATER	GRAB		10/18/2004	TAN	MONITORING WELL	TAN-1861	239	1	1	1		1				1		1	1								
RAA467	QC	WATER	FBLK		10/18/2004	TAN	FB - ISB	QC	NA	1	1	1		1				1		1	1								
RAA468	QC	WATER	FBLK		10/18/2004	TAN	FB - ISB	QC	NA	1	1	1	1	1				1	1	1	1								
RAA469	QC	WATER	FBLK		10/18/2004	TAN	FB - ISB	QC	NA	1	1	1		1				1		1	1								
RAA470	QC	WATER	TBLK		10/18/2004	TAN	TB - ISB	QC	NA					1							1								
RAA471	QC	WATER	TBLK		10/18/2004	TAN	TB - ISB	QC	NA				1	1							1								
RAA472	QC	WATER	TBLK		10/18/2004	TAN	TB - ISB	QC	NA					1							1								

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

D - Double QC Volume T - Triple QC Volume

AT1: Alkalinity

AT2: Analysis Suite #1

AT3: Chemical Oxygen Demand

AT4: Dissolved Gases

AT5: Ethane/Ethene/Methane

AT6: Field Standard Addition - QC

AT7: Gamma Screen

AT8: Microbiological Analysis

AT9: Propionate/Butyrate/Acetate/Lactate - Filtered

AT10: Sr-90

AT11: Tritium

AT12: VOCs (CLP TAL)

AT13: VOCs (CLP TAL) - MS/MSD

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, Alkalinity, COD, and Field Standard Addition - QC

Samples will be sent to IRC except Tritium and Strontium-90 which will be shipped to an off-site lab

The third duplicate, field blank, and trip blank will only be collected if needed

AED Sampling is included on wells TSF-05A, TSF-05B, TSF-25, TSF-26, and TSF-31

Propionate/Butyrate/Acetate/Lactate - Lactate changed to Lactose

Dissolved Gases = Ethane/Ethene/Methane

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Plan Table Number: INITIAL_NOV04

DRAFT

SAP Number: INEEL/EXT-2002-00779

Sampler: Carroll, R. E.

Date: 09/23/2004 Plan Table Revision: 0.0 Project: OU 1-07B ISB RA GWM - INITIAL SEMI-ANNUAL 11/04 (PM) & AED Project Manager: NELSON, L. O.

SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																				
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	A1	3A	C5	EG	F6	R5	MB	1N	RB	R8	VL	VM								
RAA525	REG/QC	GROUND WATER	DUP		11/15/2004	TAN	MONITORING WELL	TSF-05A (71)	235	1	1	1	1		1		1		1		2								
RAA526	REG	GROUND WATER	GRAB		11/15/2004	TAN	MONITORING WELL	TSF-05B (71)	270	1	1	1	1		1		1		1	2									
RAA527	REG/QC	GROUND WATER	DUP		11/15/2004	TAN	MONITORING WELL	TAN-25 (1117)	218	2	2	2	2		1	1	2	2	2	4									
RAA528	REG	GROUND WATER	GRAB		11/15/2004	TAN	MONITORING WELL	TAN-26 (1118)	389	1	1	1	1		1		1		1		2								
RAA529	REG	GROUND WATER	GRAB		11/15/2004	TAN	MONITORING WELL	TAN-27 (1009)	235	1	1	1	1				1		1	2									
RAA530	REG	GROUND WATER	GRAB		11/15/2004	TAN	MONITORING WELL	TAN-28 (1008)	240	1	1	1	1				1		1	2									
RAA531	REG	GROUND WATER	GRAB		11/15/2004	TAN	MONITORING WELL	TAN-29 (1010)	253	1	1	1	1				1		1	2									
RAA532	REG	GROUND WATER	GRAB		11/15/2004	TAN	MONITORING WELL	TAN-30A (1012)	310	1	1	1	1				1		1	2									
RAA533	REG	GROUND WATER	GRAB		11/15/2004	TAN	MONITORING WELL	TAN-31 (1219)	258	1	1	1	1		1		1		1	2									
RAA534	REG	GROUND WATER	GRAB		11/15/2004	TAN	MONITORING WELL	TAN-37A (1163)	240	1	1	1	1				1		1	2									
RAA535	REG	GROUND WATER	GRAB		11/15/2004	TAN	MONITORING WELL	TAN-37B (1163)	272	1	1	1	1				1		1	2									
RAA536	REG/QC	GROUND WATER	DUP		11/15/2004	TAN	MONITORING WELL	TAN-37C (1163)	375	2	2	2	2				2		2	4									
RAA537	REG/QC	GROUND WATER	DUP		11/15/2004	TAN	MONITORING WELL	TAN-10A (348)	233	2	2	2	2	1			2		2	4									
RAA538	REG	GROUND WATER	GRAB		11/15/2004	TAN	MONITORING WELL	TAN-D2 (339)	241	1	1	1	1				1		1	2									
RAA539	REG	GROUND WATER	GRAB		11/15/2004	TAN	MONITORING WELL	TAN-1859	250	1	1	1	1		1		1		1	2									

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

AT1: Alkalinity

AT2: Analysis Suite #1

AT3: Chemical Oxygen Demand

AT4: Ethane/Ethene/Methane

AT5: Field Standard Addition - QC

AT6: Gamma Screen

AT7: Microbiological Analysis

AT8: Propionate/Butyrate/Acetate/Lactate

AT9: Sr-90

AT10: Tritium

AT11: VOCs (CLP TAL)

AT12: VOCs (CLP TAL) - MS/MSD

AT13:

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, Alkalinity, COD, & Field Standard Addition - QC

Split samples will be collected at all locations for VOCs (TAL). One set will be sent to IRC and one set will be sent to an off-site lab.

Samples will be sent to IRC except Tritium and Strontium-90 which will be shipped to an off-site lab.

AED Sampling is included on Wells TSF-05A, TSF-05B, TAN-25, TAN-26, and TAN-31

The third duplicate, field blank, and trip blank will only be collected if needed

Propionate/Butyrate/Acetate/Lactate does not include the Lactate analysis

Analysis Suites:

Analysis Suite #1: Ammonia Nitrogen, Phosphate, Sulfate, Iron (Inorganic Analysis)

Contingencies:

Plan Table Number: INITIAL_NOV04

DRAFT

SAP Number: INEEL/EXT-2002-00779

Sampler: Carroll, R. E.

Date: 09/23/2004 Plan Table Revision: 0.0 Project: OU 1-07B ISB RA GWM - INITIAL SEMI-ANNUAL 11/04 (PM) & AED Project Manager: NELSON, L. O.

SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																				
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	A1	3A	C5	EG	F6	R5	MB	1N	RB	R8	VL	VM								
RAA540	REG	GROUND WATER	GRAB		11/15/2004	TAN	MONITORING WELL	TAN-1860	269	1	1	1	1				1		1	2									
RAA541	REG	GROUND WATER	GRAB		11/15/2004	TAN	MONITORING WELL	TAN-1861	239	1	1	1	1				1		1	2									
RAA542	QC	WATER	FBLK		11/15/2004	TAN	FB - ISB	QC	NA	1	1	1	1				1		1	2									
RAA543	QC	WATER	FBLK		11/15/2004	TAN	FB - ISB	QC	NA	1	1	1	1				1	1	1	2									
RAA544	QC	WATER	FBLK		11/15/2004	TAN	FB - ISB	QC	NA	1	1	1	1				1		1	2									
RAA545	QC	WATER	TBLK		11/15/2004	TAN	TB - ISB	QC	NA				1							1									
RAA546	QC	WATER	TBLK		11/15/2004	TAN	TB - ISB	QC	NA				1							1									
RAA547	QC	WATER	TBLK		11/15/2004	TAN	TB - ISB	QC	NA				1							1									
RAA548	QC	GROUND WATER	PES		11/15/2004	TAN	MONITORING WELL	TAN-2 (123)	240											1									
RAA549	QC	WATER	TBLK		11/15/2004	TAN	TB-ISB	QC	NA											1									

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

AT1: Alkalinity

AT2: Analysis Suite #1

AT3: Chemical Oxygen Demand

AT4: Ethane/Ethene/Methane

AT5: Field Standard Addition - QC

AT6: Gamma Screen

AT7: Microbiological Analysis

AT8: Propionate/Butyrate/Acetate/Lactate

AT9: Sr-90

AT10: Tritium

AT11: VOCs (CLP TAL)

AT12: VOCs (CLP TAL) - MS/MSD

AT13:

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, Alkalinity, COD, & Field Standard Addition - QC

Split samples will be collected at all locations for VOCs (TAL). One set will be sent to IRC and one set will be sent to an off-site lab.

Samples will be sent to IRC except Tritium and Strontium-90 which will be shipped to an off-site lab.

AED Sampling is included on Wells TSF-05A, TSF-05B, TAN-25, TAN-26, and TAN-31

The third duplicate, field blank, and trip blank will only be collected if needed

Propionate/Butyrate/Acetate/Lactate does not include the Lactate analysis

Analysis Suites:

Analysis Suite #1: Ammonia Nitrogen, Phosphate, Sulfate, Iron (Inorganic Analysis)

Contingencies:

Sampling and Analysis Plan Table for Chemical and Radiological Analysis

11/11/2004 10:48 AM

Plan Table Number: INITIAL_DEC04

SAP Number: INEEL/EXT-2002-00779

Sampler: Carroll, R. E.

Date: 11/11/2004 Plan Table Revision: 0.0 Project: OU 1-07B ISB RA GWM - INITIAL MONTHLY 12/04 (PM) & AED Project Manager: NELSON, L. O.

SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
										A1	3A	C5	EG	F6	R5	MB	1N	RB	R8	VL	VM								
RAA600	REG	GROUND WATER	GRAB		12/13/04	TAN	MONITORING WELL	TSF-05A (71)	235	1	1	1	1		1		1		1	1								
RAA601	REG	GROUND WATER	GRAB		12/13/04	TAN	MONITORING WELL	TSF-05B (71)	270	1	1	1	1		1		1		1	1								
RAA602	REG/QC	GROUND WATER	DUP		12/13/04	TAN	MONITORING WELL	TAN-25 (1117)	218	2	2	2	2		1	1	2	2	2	2								
RAA603	REG	GROUND WATER	GRAB		12/13/04	TAN	MONITORING WELL	TAN-26 (1118)	389	1	1	1	1		1		1		1	1								
RAA604	REG/QC	GROUND WATER	DUP		12/13/04	TAN	MONITORING WELL	TAN-27 (1009)	235	2	2	2	2				2		2	2								
RAA605	REG	GROUND WATER	GRAB		12/13/04	TAN	MONITORING WELL	TAN-28 (1008)	240	1	1	1	1				1		1	1								
RAA606	REG	GROUND WATER	GRAB		12/13/04	TAN	MONITORING WELL	TAN-29 (1010)	253	1	1	1	1	1			1		1	1								
RAA607	REG	GROUND WATER	GRAB		12/13/04	TAN	MONITORING WELL	TAN-30A (1012)	313	1	1	1	1				1		1	1								
RAA608	REG	GROUND WATER	GRAB		12/13/04	TAN	MONITORING WELL	TAN-31 (1219)	258	1	1	1	1		1		1		1	1								
RAA609	REG	GROUND WATER	GRAB		12/13/04	TAN	MONITORING WELL	TAN-37A(1163)	240	1	1	1	1				1		1	1								
RAA610	REG/QC	GROUND WATER	DUP		12/13/04	TAN	MONITORING WELL	TAN-37B (1163)	270	2	2	2	2				2		2	2								
RAA611	REG	GROUND WATER	GRAB		12/13/04	TAN	MONITORING WELL	TAN-37C (1163)	375	1	1	1	1				1		1	1								
RAA612	REG	GROUND WATER	GRAB		12/13/04	TAN	MONITORING WELL	TAN-10A (348)	233	1	1	1	1				1		1	1								
RAA613	REG	GROUND WATER	GRAB		12/13/04	TAN	MONITORING WELL	TAN-D2 (339)	241	1	1	1	1				1		1		1							
RAA614	REG	GROUND WATER	GRAB		12/13/04	TAN	MONITORING WELL	TAN-1859	250	1	1	1	1		1		1		1	1								

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

AT1: Alkalinity

AT2: Analysis Suite #1

AT3: Chemical Oxygen Demand

AT4: Ethane/Ethene/Methane

AT5: Field Standard Addition - QC

AT6: Gamma Screen

AT7: Microbiological Analysis

AT8: Propionate/Butyrate/Acetate/Lactate

AT9: Sr-90

AT10: Tritium

AT11: VOCs (CLP TAL)

AT12: VOCs (CLP TAL) - MS/MSD

AT13:

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, Alkalinity, COD, and Field Standard Addition - QC

Samples will be sent to IRC except Tritium and Strontium-90 which will be shipped to an off-site lab

The third duplicate, field blank, and trip blank will only be collected if needed

AED Sampling is included on wells TSF-05A, TSF-05B, TSF-25, TSF-26, and TSF-31

Propionate/Butyrate/Acetate/Lactate does not include the Lactate analysis

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Plan Table Number: INITIAL_DEC04

SAP Number: INEEL/EXT-2002-00779 Sampler: Carroll, R. E.

Date: 11/11/2004 Plan Table Revision: 0.0 Project: OU 1-07B ISB RA GWM - INITIAL MONTHLY 12/04 (PM) & AED Project Manager: NELSON, L. O. SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																				
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	A1	3A	C5	EG	F6	R5	MB	1N	RB	R8	VL	VM								
RAA615	REG	GROUND WATER	GRAB		12/13/04	TAN	MONITORING WELL	TAN-1860	269	1	1	1	1				1		1	1									
RAA616	REG	GROUND WATER	GRAB		12/13/04	TAN	MONITORING WELL	TAN-1861	239	1	1	1	1				1		1		1								
RAA617	QC	WATER	FBLK		12/13/04	TAN	FB - ISB	QC	NA	1	1	1	1				1		1	1									
RAA618	QC	WATER	FBLK		12/13/04	TAN	FB - ISB	QC	NA	1	1	1	1				1	1	1	1									
RAA619	QC	WATER	FBLK		12/13/04	TAN	FB - ISB	QC	NA	1	1	1	1				1		1	1									
RAA620	QC	WATER	TBLK		12/13/04	TAN	TB - ISB	QC	NA				1							1									
RAA621	QC	WATER	TBLK		12/13/04	TAN	TB - ISB	QC	NA				1							1									
RAA622	QC	WATER	TBLK		12/13/04	TAN	TB - ISB	QC	NA				1							1									

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

AT1: Alkalinity

AT2: Analysis Suite #1

AT3: Chemical Oxygen Demand

AT4: Ethane/Ethene/Methane

AT5: Field Standard Addition - QC

AT6: Gamma Screen

AT7: Microbiological Analysis

AT8: Propionate/Butyrate/Acetate/Lactate

AT9: Sr-90

AT10: Tritium

AT11: VOCs (CLP TAL)

AT12: VOCs (CLP TAL) - MS/MSD

AT13:

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, Alkalinity, COD, and Field Standard Addition - QC

Samples will be sent to IRC except Tritium and Strontium-90 which will be shipped to an off-site lab

The third duplicate, field blank, and trip blank will only be collected if needed

AED Sampling is included on wells TSF-05A, TSF-05B, TSF-25, TSF-26, and TSF-31

Propionate/Butyrate/Acetate/Lactate does not include the Lactate analysis

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Plan Table Number: INITIAL_JAN05

SAP Number: INEEL/EXT-2002-00779 Sampler: Carroll, R. E.

Date: 01/10/2005 Plan Table Revision: 2.0 Project: OU 1-07B ISB RA GWM - INITIAL MONTHLY 1/05 (PM) & AED Project Manager: NELSON, L. O. SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	A1	3A	C5	Y4	EG	F6	R5	MB	1N	RB	D5	R8	VL	VM						
RAA675	REG	GROUND WATER	GRAB		01/17/2005	TAN	MONITORING WELL	TSF-05A	235	1	1	1	1	1		1		1			1	1							
RAA676	REG	GROUND WATER	GRAB		01/17/2005	TAN	MONITORING WELL	TSF-05B	270	1	1	1	1	1		1		1		1	1	1							
RAA677	REG/QC	GROUND WATER	DUP		01/17/2005	TAN	MONITORING WELL	TAN-25	218	2	2	2	2	2		1	1	2	2	1	2	2							
RAA678	REG	GROUND WATER	GRAB		01/17/2005	TAN	MONITORING WELL	TAN-26	389	1	1	1		1		1		1			1	1							
RAA679	REG/QC	GROUND WATER	DUP		01/17/2005	TAN	MONITORING WELL	TAN-27	235	2	2	2	1	2				2			2	2							
RAA680	REG	GROUND WATER	GRAB		01/17/2005	TAN	MONITORING WELL	TAN-28	240	1	1	1		1				1		1	1	1							
RAA681	REG	GROUND WATER	GRAB		01/17/2005	TAN	MONITORING WELL	TAN-29	253	1	1	1		1	1			1			1	1							
RAA682	REG	GROUND WATER	GRAB		01/17/2005	TAN	MONITORING WELL	TAN-30A	313	1	1	1	1	1				1			1		1						
RAA683	REG	GROUND WATER	GRAB		01/17/2005	TAN	MONITORING WELL	TAN-31	258	1	1	1		1		1		1			1	1							
RAA684	REG	GROUND WATER	GRAB		01/17/2005	TAN	MONITORING WELL	TAN-37A	240	1	1	1		1				1			1	1							
RAA685	REG/QC	GROUND WATER	DUP		01/17/2005	TAN	MONITORING WELL	TAN-37B	270	2	2	2		2				2			2	2							
RAA686	REG	GROUND WATER	GRAB		01/17/2005	TAN	MONITORING WELL	TAN-37C	375	1	1	1		1				1			1	1							
RAA687	REG	GROUND WATER	GRAB		01/17/2005	TAN	MONITORING WELL	TAN-10A	233	1	1	1		1				1			1	1							
RAA688	REG	GROUND WATER	GRAB		01/17/2005	TAN	MONITORING WELL	TAN-D2	241	1	1	1		1				1			1	1							
RAA689	REG	GROUND WATER	GRAB		01/17/2005	TAN	MONITORING WELL	TAN-1859	250	1	1	1	1	1		1		1		1	1		1						

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

AT1: Alkalinity

AT2: Analysis Suite #1

AT3: Chemical Oxygen Demand

AT4: Dissolved Gases

AT5: Ethane/Ethene/Methane

AT6: Field Standard Addition - QC

AT7: Gamma Screen

AT8: Microbiological Analysis

AT9: Propionate/Butyrate/Acetate/Lactate

AT10: Sr-90

AT11: Tension

AT12: Tritium

AT13: VOCs (CLP TAL)

AT14: VOCs (CLP TAL) - MS/MSD

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, Alkalinity, COD, and Field Standard Addition - QC

Samples will be sent to IRC except Tritium and Strontium-90 which will be shipped to an off-site lab

The third duplicate, field blank, and trip blank will only be collected if needed

AED Sampling is included on wells TAN-1859, TSF-05A, TSF-05B, TAN-25, TAN-26, and TAN-31

Propionate/Butyrate/Acetate/Lactate includes Lactose not Lactate

Tension - Interfacial Tension and Surface Tension

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Sampling and Analysis Plan Table for Chemical and Radiological Analysis

01/10/2005 02:37 PM

Plan Table Number: INITIAL_JAN05

SAP Number: INEEL/EXT-2002-00779

Sampler: Carroll, R. E.

Date: 01/10/2005 Plan Table Revision: 2.0 Project: OU 1-07B ISB RA GWM - INITIAL MONTHLY 1/05 (PM) & AED Project Manager: NELSON, L. O.

SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	A1	3A	C5	Y4	EG	F6	R5	MB	1N	RB	D5	R8	VL	VM						
RAA690	REG	GROUND WATER	GRAB		01/17/2005	TAN	MONITORING WELL	TAN-1860	269	1	1	1		1				1			1	1							
RAA691	REG	GROUND WATER	GRAB		01/17/2005	TAN	MONITORING WELL	TAN-1861	239	1	1	1		1				1			1	1							
RAA692	QC	WATER	FBLK		01/17/2005	TAN	FB - ISB	QC	NA	1	1	1		1				1			1	1							
RAA693	QC	WATER	FBLK		01/17/2005	TAN	FB - ISB	QC	NA	1	1	1		1				1	1		1	1							
RAA694	QC	WATER	FBLK		01/17/2005	TAN	FB - ISB	QC	NA	1	1	1		1				1			1	1							
RAA695	QC	WATER	TBLK		01/17/2005	TAN	TB - ISB	QC	NA					1								1							
RAA696	QC	WATER	TBLK		01/17/2005	TAN	TB - ISB	QC	NA					1								1							
RAA697	QC	WATER	TBLK		01/17/2005	TAN	TB - ISB	QC	NA					1								1							

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

AT1: Alkalinity

AT2: Analysis Suite #1

AT3: Chemical Oxygen Demand

AT4: Dissolved Gases

AT5: Ethane/Ethene/Methane

AT6: Field Standard Addition - QC

AT7: Gamma Screen

AT8: Microbiological Analysis

AT9: Propionate/Butyrate/Acetate/Lactate

AT10: Sr-90

AT11: Tension

AT12: Tritium

AT13: VOCs (CLP TAL)

AT14: VOCs (CLP TAL) - MS/MSD

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, Alkalinity, COD_3 and Field Standard Addition - QC

Samples will be sent to IRC except Tritium and Strontium-90 which will be shipped to an off-site lab

The third duplicate, field blank, and trip blank will only be collected if needed

AED Sampling is included on wells TAN-1859, TSF-05A, TSF-05B, TAN-25, TAN-26, and TAN-31

Propionate/Butyrate/Acetate/Lactate includes Lactose not Lactate

Tension - Interfacial Tension and Surface Tension

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Sampling and Analysis Plan Table for Chemical and Radiological Analysis

02/08/2005 09:46 AM

Plan Table Number: INITIAL_FEB05

SAP Number: INEEL/EXT-2002-00779

Sampler: Carroll, R. E.

Date: 02/02/2005 Plan Table Revision: 1.0 Project: OU 1-07B ISB RA GWM - INITIAL MONTHLY 2/05 (PM) & AED Project Manager: NELSON, L. O.

SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	A1	3A	C5	Y4	EG	F6	R5	MB	1N	RB	R8	VL	VM							
RAA700	REG	GROUND WATER	GRAB		02/14/2005	TAN	MONITORING WELL	TSF-05A	235	1	1	1	1	1		1		1		1	1								
RAA701	REG	GROUND WATER	GRAB		02/14/2005	TAN	MONITORING WELL	TSF-05B	270	1	1	1	1	1		1		1		1	1								
RAA702	REG/QC	GROUND WATER	DUP		02/14/2005	TAN	MONITORING WELL	TAN-25	218	2	2	2	2	2		1	1	2	2	2	2								
RAA703	REG	GROUND WATER	GRAB		02/14/2005	TAN	MONITORING WELL	TAN-26	389	1	1	1		1		1		1		1	1								
RAA704	REG/QC	GROUND WATER	DUP		02/14/2005	TAN	MONITORING WELL	TAN-27	235	1	1	1	1	1				1		1	1								
RAA705	REG	GROUND WATER	GRAB		02/14/2005	TAN	MONITORING WELL	TAN-28	240	1	1	1		1				1		1	1								
RAA706	REG/QC	GROUND WATER	DUP		02/14/2005	TAN	MONITORING WELL	TAN-29	253	2	2	2		2	1			2		2	2								
RAA707	REG	GROUND WATER	GRAB		02/14/2005	TAN	MONITORING WELL	TAN-30A	313	1	1	1	1	1				1		1	1								
RAA708	REG	GROUND WATER	GRAB		02/14/2005	TAN	MONITORING WELL	TAN-31	258	1	1	1		1		1		1		1	1								
RAA709	REG	GROUND WATER	GRAB		02/14/2005	TAN	MONITORING WELL	TAN-37A	240	1	1	1		1				1		1		1							
RAA710	REG	GROUND WATER	GRAB		02/14/2005	TAN	MONITORING WELL	TAN-37B	270	1	1	1		1				1		1	1								
RAA711	REG	GROUND WATER	GRAB		02/14/2005	TAN	MONITORING WELL	TAN-37C	375	1	1	1		1				1		1	1								
RAA712	REG	GROUND WATER	GRAB		02/14/2005	TAN	MONITORING WELL	TAN-10A	233	2	2	2		2				2		2	2								
RAA713	REG	GROUND WATER	GRAB		02/14/2005	TAN	MONITORING WELL	TAN-D2	241	1	1	1		1				1		1	1								
RAA714	REG	GROUND WATER	GRAB		02/14/2005	TAN	MONITORING WELL	TAN-1859	250	1	1	1	1	1		1		1		1		1							

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identifcation number will appear on the sample labels.

AT1: Alkalinity

AT2: Analysis Suite #1

AT3: Chemical Oxygen Demand

AT4: Dissolved Gases

AT5: Ethane/Ethene/Methane

AT6: Field Standard Addition - QC

AT7: Gamma Screen

AT8: Microbiological Analysis

AT9: Propionate/Butyrate/Acetate/Lactate

AT10: Sr-90

AT11: Tritium

AT12: VOCs (CLP TAL)

AT13: VOCs (CLP TAL) - MS/MSD

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, Alkalinity, COD, and Field Standard Addition - QC

Samples will be sent to IRC except Tritium and Strontium-90 which will be shipped to an off-site lab

The third duplicate, field blank, and trip blank will only be collected if needed

AED Sampling is included on wells TSF-05A, TSF-05B, TAN-25, TAN-1859, and TAN-31

Propionate/Butyrate/Acetate/Lactate includes Lactose not Lactate

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Sampling and Analysis Plan Table for Chemical and Radiological Analysis

02/08/2005 09:46 AM

Plan Table Number: INITIAL_FEB05

SAP Number: INEEL/EXT-2002-00779

Sampler: Carroll, R. E.

Date: 02/02/2005 Plan Table Revision: 1.0 Project: OU 1-07B ISB RA GWM - INITIAL MONTHLY 2/05 (PM) & AED Project Manager: NELSON, L. O.

SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																				
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	A1	3A	C5	Y4	EG	F6	R5	MB	1N	RB	R8	VL	VM							
RAA715	REG	GROUND WATER	GRAB		02/14/2005	TAN	MONITORING WELL	TAN-1860	269	1	1	1		1	1			1		1	1								
RAA716	REG	GROUND WATER	GRAB		02/14/2005	TAN	MONITORING WELL	TAN-1861	239	1	1	1		1				1		1	1								
RAA717	QC	WATER	FBLK		02/14/2005	TAN	FB - ISB	QC	NA	1	1	1	1	1				1		1	1								
RAA718	QC	WATER	FBLK		02/14/2005	TAN	FB - ISB	QC	NA	1	1	1	1	1				1	1	1	1								
RAA719	QC	WATER	FBLK		02/14/2005	TAN	FB - ISB	QC	NA	1	1	1	1	1				1		1	1								
RAA720	QC	WATER	TBLK		02/14/2005	TAN	TB - ISB	QC	NA				1	1							1								
RAA721	QC	WATER	TBLK		02/14/2005	TAN	TB - ISB	QC	NA				1	1							1								
RAA722	QC	WATER	TBLK		02/14/2005	TAN	TB - ISB	QC	NA				1	1							1								

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

AT1: Alkalinity

AT2: Analysis Suite #1

AT3: Chemical Oxygen Demand

AT4: Dissolved Gases

AT5: Ethane/Ethene/Methane

AT6: Field Standard Addition - QC

AT7: Gamma Screen

AT8: Microbiological Analysis

AT9: Propionate/Butyrate/Acetate/Lactate

AT10: Sr-90

AT11: Tritium

AT12: VOCs (CLP TAL)

AT13: VOCs (CLP TAL) - MS/MSD

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, Alkalinity, COD_2 and Field Standard Addition - QC

Samples will be sent to IRC except Tritium and Strontium-90 which will be shipped to an off-site lab

The third duplicate, field blank, and trip blank will only be collected if needed

AED Sampling is included on wells T5F-05A, T5F-05B, TAN-25, TAN-1859, and TAN-31

Propionate/Butyrate/Acetate/Lactate includes Lactose not Lactate

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Plan Table Number: INITIAL_MAR05

DRAFT

SAP Number: INEEL/EXT-2002-00779

Sampler: Carroll, R. E.

Date: 09/23/2004 Plan Table Revision: 0.0 Project: OU 1-07B ISB RA GWM - INITIAL MONTHLY 3/05 (PM) & AED Project Manager: NELSON, L. O.

SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																				
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	A1	3A	C5	EG	F6	R5	MB	1N	RB	R8	VL	VM								
RAA775	REG	GROUND WATER	GRAB		03/07/2005	TAN	MONITORING WELL	TSF-05A (71)	235	1	1	1	1		1		1		1	1								
RAA776	REG	GROUND WATER	GRAB		03/07/2005	TAN	MONITORING WELL	TSF-05B (71)	270	1	1	1	1		1		1		1	1								
RAA777	REG/QC	GROUND WATER	DUP		03/07/2005	TAN	MONITORING WELL	TAN-25 (1117)	218	2	2	2	2		1	1	2	2	2	2								
RAA778	REG	GROUND WATER	GRAB		03/07/2005	TAN	MONITORING WELL	TAN-26 (1118)	389	1	1	1	1		1		1		1	1								
RAA779	REG/QC	GROUND WATER	DUP		03/07/2005	TAN	MONITORING WELL	TAN-27 (1009)	235	1	1	1	1				1		1	1								
RAA780	REG	GROUND WATER	GRAB		03/07/2005	TAN	MONITORING WELL	TAN-28 (1008)	240	1	1	1	1				1		1	1								
RAA781	REG/QC	GROUND WATER	DUP		03/07/2005	TAN	MONITORING WELL	TAN-29 (1010)	253	2	2	2	2	1			2		2	2								
RAA782	REG	GROUND WATER	GRAB		03/07/2005	TAN	MONITORING WELL	TAN-30A (1012)	313	1	1	1	1				1		1	1								
RAA783	REG	GROUND WATER	GRAB		03/07/2005	TAN	MONITORING WELL	TAN-31 (1219)	258	1	1	1	1		1		1		1	1								
RAA784	REG	GROUND WATER	GRAB		03/07/2005	TAN	MONITORING WELL	TAN-37A(1163)	240	1	1	1	1				1		1		1								
RAA785	REG	GROUND WATER	GRAB		03/07/2005	TAN	MONITORING WELL	TAN-37B (1163)	270	1	1	1	1				1		1	1								
RAA786	REG	GROUND WATER	GRAB		03/07/2005	TAN	MONITORING WELL	TAN-37C (1163)	375	1	1	1	1				1		1	1								
RAA787	REG	GROUND WATER	GRAB		03/07/2005	TAN	MONITORING WELL	TAN-10A (348)	233	2	2	2	2				2		2	2								
RAA788	REG	GROUND WATER	GRAB		03/07/2005	TAN	MONITORING WELL	TAN-D2 (339)	241	1	1	1	1				1		1	1								
RAA789	REG	GROUND WATER	GRAB		03/07/2005	TAN	MONITORING WELL	TAN-1859	250	1	1	1	1		1		1		1		1								

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number. The complete sample identification number will appear on the sample labels.

AT1: Alkalinity

AT2: Analysis Suite #1

AT3: Chemical Oxygen Demand

AT4: Ethane/Ethene/Methane

AT5: Field Standard Addition - QC

AT6: Gamma Screen

AT7: Microbiological Analysis

AT8: Propionate/Butyrate/Acetate/Lactate

AT9: Sr-90

AT10: Tritium

AT11: VOCs (CLP TAL)

AT12: VOCs (CLP TAL) - MS/MSD

AT13:

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, Alkalinity, COD, and Field Standard Addition - QC

Samples will be sent to IRC except Tritium and Strontium-90 which will be shipped to an off-site lab

The third duplicate, field blank, and trip blank will only be collected if needed

AED Sampling is included on wells TSF-05A, TSF-05B, TSF-25, TSF-26, and TSF-31

Propionate/Butyrate/Acetate/Lactate does not include the Lactate analysis

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Plan Table Number: INITIAL_MAR05

DRAFT

SAP Number: INEEL/EXT-2002-00779

Sampler: Carroll, R. E.

Date: 09/23/2004 Plan Table Revision: 0.0 Project: OU 1-07B ISB RA GWM - INITIAL MONTHLY 3/05 (PM) & AED Project Manager: NELSON, L. O. SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																				
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	A1	3A	C5	EG	F6	R5	MB	1N	RB	R8	VL	VM								
RAA790	REG	GROUND WATER	GRAB		03/07/2005	TAN	MONITORING WELL	TAN-1860	269	1	1	1	1				1		1	1									
RAA791	REG	GROUND WATER	GRAB		03/07/2005	TAN	MONITORING WELL	TAN-1861	239	1	1	1	1				1		1	1									
RAA792	QC	WATER	FBLK		03/07/2005	TAN	FB - ISB	QC	NA	1	1	1	1				1		1	1									
RAA793	QC	WATER	FBLK		03/07/2005	TAN	FB - ISB	QC	NA	1	1	1	1				1	1	1	1									
RAA794	QC	WATER	FBLK		03/07/2005	TAN	FB - ISB	QC	NA	1	1	1	1				1		1	1									
RAA795	QC	WATER	TBLK		03/07/2005	TAN	TB - ISB	QC	NA				1							1									
RAA796	QC	WATER	TBLK		03/07/2005	TAN	TB - ISB	QC	NA				1							1									
RAA797	QC	WATER	TBLK		03/07/2005	TAN	TB - ISB	QC	NA				1							1									

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

AT1: Alkalinity

AT2: Analysis Suite #1

AT3: Chemical Oxygen Demand

AT4: Ethane/Ethene/Methane

AT5: Field Standard Addition - QC

AT6: Gamma Screen

AT7: Microbiological Analysis

AT8: Propionate/Butyrate/Acetate/Lactate

AT9: Sr-90

AT10: Tritium

AT11: VOCs (CLP TAL)

AT12: VOCs (CLP TAL) - MS/MSD

AT13:

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, Alkalinity, COD, and Field Standard Addition - QC

Samples will be sent to IRC except Tritium and Strontium-90 which will be shipped to an off-site lab

The third duplicate, field blank, and trip blank will only be collected if needed

AED Sampling is included on wells TSF-05A, TSF-05B, TSF-25, TSF-26, and TSF-31

Propionate/Butyrate/Acetate/Lactate does not include the Lactate analysis

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Sampling and Analysis Plan Table for Chemical and Radiological Analysis

04/06/2005 05:00 PM

Plan Table Number: INITIAL_APR05

SAP Number: INEEL/EXT-2002-00779

Sampler: Carroll, R. E.

Date: 04/06/2005 Plan Table Revision: 1.0 Project: OU 1-07B ISB RA GWM - INITIAL MONTHLY APRIL 2005 (PM) & AED Project Manager: NELSON, L. O.

SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	A1	3A	C5	Y4	EG	F6	R5	MB	1N	RB	R8	VL	VM							
RAA810810	REG	GROUND WATER	GRAB		04/11/2005	TAN	MONITORING WELL	TSF-05A	235	1	1	1	1	1		1		1		1	1								
RAA810811	REG	GROUND WATER	GRAB		04/11/2005	TAN	MONITORING WELL	TSF-05B	270	1	1	1	1	1		1		1		1	1								
RAA810812	REG	GROUND WATER	GRAB		04/11/2005	TAN	MONITORING WELL	TAN-25	218	1	1	1	1	1		1	1	1	2	1	1								
RAA810813	REG	GROUND WATER	GRAB		04/11/2005	TAN	MONITORING WELL	TAN-26	389	1	1	1		1		1		1		1	1								
RAA810814	REG/QC	GROUND WATER	DUP		04/11/2005	TAN	MONITORING WELL	TAN-27	235	1	1	1	1	1				1		1	1								
RAA810815	REG	GROUND WATER	GRAB		04/11/2005	TAN	MONITORING WELL	TAN-28	240	1	1	1		1	1			1		1	1								
RAA810816	REG/QC	GROUND WATER	DUP		04/11/2005	TAN	MONITORING WELL	TAN-29	253	2	2	2		2	1			2		2	2								
RAA810817	REG	GROUND WATER	GRAB		04/11/2005	TAN	MONITORING WELL	TAN-30A	313	1	1	1	1	1				1		1	1								
RAA810818	REG	GROUND WATER	GRAB		04/11/2005	TAN	MONITORING WELL	TAN-31	258	1	1	1	1	1		1		1		1	1								
RAA810819	REG	GROUND WATER	GRAB		04/11/2005	TAN	MONITORING WELL	TAN-37A	240	1	1	1		1				1		1		1							
RAA810820	REG	GROUND WATER	GRAB		04/11/2005	TAN	MONITORING WELL	TAN-37B	270	1	1	1		1				1		1	1								
RAA810821	REG	GROUND WATER	GRAB		04/11/2005	TAN	MONITORING WELL	TAN-37C	375	1	1	1		1				1		1	1								
RAA810822	REG	GROUND WATER	GRAB		04/11/2005	TAN	MONITORING WELL	TAN-10A	233	2	2	2		2				2		2	2								
RAA810823	REG	GROUND WATER	GRAB		04/11/2005	TAN	MONITORING WELL	TAN-D2	241	1	1	1		1				1		1	1								
RAA810824	REG	GROUND WATER	GRAB		04/11/2005	TAN	MONITORING WELL	TAN-1859	250	1	1	1	1	1		1		1		1		1							

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

AT1: Alkalinity

AT2: Analysis Suite #1

AT3: Chemical Oxygen Demand

AT4: Dissolved Gases

AT5: Ethane/Ethene/Methane

AT6: Field Standard Addition - QC

AT7: Gamma Screen

AT8: Microbiological Analysis

AT9: Propionate/Butyrate/Acetate/Lactate

AT10: Sr-90

AT11: Tritium

AT12: VOCs (CLP TAL)

AT13: VOCs (CLP TAL) - MS/MSD

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, Alkalinity, COD, and Field Standard Addition - QC

Samples will be sent to IRC except Tritium which will be shipped to an off-site lab

AED Sampling is included on wells TSF-05A, TSF-05B, TAN-25, TAN-1859, and TAN-31

Propionate/Butyrate/Acetate/Lactate includes Lactose not Lactate

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Plan Table Number: INITIAL_APR05

SAP Number: INEEL/EXT-2002-00779 Sampler: Carroll, R. E.

Date: 04/06/2005 Plan Table Revision: 1.0 Project: OU 1-07B ISB RA GWM - INITIAL MONTHLY APRIL 2005 (PM) & AED Project Manager: NELSON, L. O. SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																	
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	A1	3A	C5	Y4	EG	F6	R5	MB	1N	RB	R8	VL	VM							
RAA810825	REG	GROUND WATER	GRAB		04/11/2005	TAN	MONITORING WELL	TAN-1860	269	1	1	1		1				1		1	1								
RAA810826	REG	GROUND WATER	GRAB		04/11/2005	TAN	MONITORING WELL	TAN-1861	239	1	1	1		1				1		1	1								
RAA810827	REG	GROUND WATER	GRAB		04/11/2005	TAN	MONITORING WELL	TAN-09 (345)	293	1	1	1		1		1		1		1	1								
RAA810828	QC	WATER	FBLK		04/11/2005	TAN	FB - ISB	QC	NA	1	1	1	1	1				1		1	1								
RAA810829	QC	WATER	FBLK		04/11/2005	TAN	FB - ISB	QC	NA	1	1	1	1	1				1	1	1	1								
RAA810830	QC	WATER	TBLK		04/11/2005	TAN	TB - ISB	QC	NA				1	1							1								
RAA810831	QC	WATER	TBLK		04/11/2005	TAN	TB - ISB	QC	NA				1	1							1								

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

AT1: Alkalinity

AT2: Analysis Suite #1

AT3: Chemical Oxygen Demand

AT4: Dissolved Gases

AT5: Ethane/Ethene/Methane

AT6: Field Standard Addition - QC

AT7: Gamma Screen

AT8: Microbiological Analysis

AT9: Propionate/Butyrate/Acetate/Lactate

AT10: Sr-90

AT11: Tritium

AT12: VOCs (CLP TAL)

AT13: VOCs (CLP TAL) - MS/MSD

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, Alkalinity, COD, and Field Standard Addition - QC

Samples will be sent to IRC except Tritium which will be shipped to an off-site lab

AED Sampling is included on wells TSF-05A, TSF-05B, TAN-25, TAN-1859, and TAN-31

Propionate/Butyrate/Acetate/Lactate includes Lactose not Lactate

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Plan Table Number: INITIAL_MAY05

SAP Number: INEEL/EXT-2002-00779 Sampler: Carroll, R. E.

Date: 04/27/2005 Plan Table Revision: 2.0 Project: OU 1-07B ISB RA GWM - INITIAL MONTHLY MAY 2005 (PM) & AED Project Manager: NELSON, L. O. SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																				
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	A1	3A	C5	Y4	EG	F6	R5	MB	1N	RB	R8	VL								
RAA850	REG/QC	GROUND WATER	DUP		05/09/2005	TAN	MONITORING WELL	TSF-05A	235	2	2	2	2	2		1		2		2	2								
RAA851	REG/QC	GROUND WATER	DUP		05/09/2005	TAN	MONITORING WELL	TSF-05B	270	2	2	2	2	2		1		2		2	2								
RAA852	REG	GROUND WATER	GRAB		05/09/2005	TAN	MONITORING WELL	TAN-25	218	1	1	1	1	1		1	1	1	D[2]	1	1								
RAA853	REG	GROUND WATER	GRAB		05/09/2005	TAN	MONITORING WELL	TAN-26	389	1	1	1		1		1		1		1	1								
RAA854	REG	GROUND WATER	GRAB		05/09/2005	TAN	MONITORING WELL	TAN-27	235	1	1	1	1	1				1		1	1								
RAA855	REG	GROUND WATER	GRAB		05/09/2005	TAN	MONITORING WELL	TAN-28	240	1	1	1		1	1			1		1	1								
RAA856	REG	GROUND WATER	GRAB		05/09/2005	TAN	MONITORING WELL	TAN-29	253	1	1	1		1	1			1		1	1								
RAA857	REG	GROUND WATER	GRAB		05/09/2005	TAN	MONITORING WELL	TAN-30A	313	1	1	1	1	1				1		1	1								
RAA858	REG	GROUND WATER	GRAB		05/09/2005	TAN	MONITORING WELL	TAN-31	258	1	1	1	1	1		1		1		1	1								
RAA859	REG	GROUND WATER	GRAB		05/09/2005	TAN	MONITORING WELL	TAN-37A	240	1	1	1		1				1		D[1]	D[1]								
RAA860	REG	GROUND WATER	GRAB		05/09/2005	TAN	MONITORING WELL	TAN-37B	270	1	1	1		1				1		1	1								
RAA861	REG	GROUND WATER	GRAB		05/09/2005	TAN	MONITORING WELL	TAN-37C	375	1	1	1		1				1		1	1								
RAA862	REG	GROUND WATER	GRAB		05/09/2005	TAN	MONITORING WELL	TAN-10A	233	1	1	1		1				1		1	1								
RAA863	REG	GROUND WATER	GRAB		05/09/2005	TAN	MONITORING WELL	TAN-D2	241	1	1	1		1				1		1	1								
RAA864	REG	GROUND WATER	GRAB		05/09/2005	TAN	MONITORING WELL	TAN-1859	250	1	1	1	1	1		1		1		D[1]	D[1]								

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number. The complete sample identification number will appear on the sample labels.

D - Double QC Volume T - Triple QC Volume

AT1: Alkalinity

AT2: Analysis Suite #1

AT3: Chemical Oxygen Demand

AT4: Dissolved Gases

AT5: Ethane/Ethene/Methane

AT6: Field Standard Addition - QC

AT7: Gamma Screen

AT8: Microbiological Analysis

AT9: Propionate/Butyrate/Acetate/Lactate - Filtered

AT10: Sr-90

AT11: Tritium

AT12: VOCs (CLP TAL)

AT13:

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, Alkalinity, COD, and Field Standard Addition - QC

Samples will be sent to IRC except Tritium which will be shipped to an off-site lab

AED Sampling is included on wells TSF-05A, TSF-05B, TAN-25, TAN-1859, and TAN-31

Propionate/Butyrate/Acetate/Lactate includes Lactose not Lactate

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Plan Table Number: INITIAL_MAY05

SAP Number: INEEL/EXT-2002-00779

Sampler: Carroll, R. E.

Date: 04/27/2005 Plan Table Revision: 2.0 Project: OU 1-07B ISB RA GWM - INITIAL MONTHLY MAY 2005 (PM) & AED Project Manager: NELSON, L. O. SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																				
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	A1	3A	C5	Y4	EG	F6	R5	MB	1N	RB	R8	VL								
RAA865	REG	GROUND WATER	GRAB		05/09/2005	TAN	MONITORING WELL	TAN-1860	269	1	1	1		1				1		1	1								
RAA866	REG	GROUND WATER	GRAB		05/09/2005	TAN	MONITORING WELL	TAN-1861	239	1	1	1		1				1		1	1								
RAA867	REG	GROUND WATER	GRAB		05/09/2005	TAN	MONITORING WELL	TAN-09 (346)	293	1	1	1		1				1		1	1								
RAA868	QC	WATER	FBLK		05/09/2005	TAN	FB - ISB	QC	NA	1	1	1	1	1				1		1	1								
RAA869	QC	WATER	FBLK		05/09/2005	TAN	FB - ISB	QC	NA	1	1	1	1	1				1	1	1	1								
RAA870	QC	WATER	TBLK		05/09/2005	TAN	TB - ISB	QC	NA				1	1							1								
RAA871	QC	WATER	TBLK		05/09/2005	TAN	TB - ISB	QC	NA				1	1							1								

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

D - Double QC Volume T - Triple QC Volume

AT1: Alkalinity

AT2: Analysis Suite #1

AT3: Chemical Oxygen Demand

AT4: Dissolved Gases

AT5: Ethane/Ethene/Methane

AT6: Field Standard Addition - QC

AT7: Gamma Screen

AT8: Microbiological Analysis

AT9: Propionate/Butyrate/Acetate/Lactate - Filtered

AT10: Sr-90

AT11: Tritium

AT12: VOCs (CLP TAL)

AT13:

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, Alkalinity, COD_3, and Field Standard Addition - QC

Samples will be sent to IRC except Tritium which will be shipped to an off-site lab

AED Sampling is included on wells TSF-05A, TSF-05B, TAN-25, TAN-1859, and TAN-31

Propionate/Butyrate/Acetate/Lactate includes Lactose not Lactate

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Plan Table Number: INITIAL_JUNE05

SAP Number: INEEL/EXT-2002-00779

Sampler: Carroll, R. E.

Date: 06/02/2005 Plan Table Revision: 0.0 Project: OU 1-07B ISB RA GWM - INITIAL SEMI-ANNUAL JUNE 2005 Project Manager: NELSON, L. O. SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																				
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
										A1	3A	C5	Y4	EG	F6	R5	MB	1N	RB	R8	VL								
RAA875	REG	GROUND WATER	GRAB		6/13/05	TAN	MONITORING WELL	TSF-05A	235	1	1	1	1	1		1		1		1	2								
RAA876	REG	GROUND WATER	GRAB		6/13/05	TAN	MONITORING WELL	TSF-05B	270	1	1	1	1	1		1		1		1	2								
RAA877	REG	GROUND WATER	GRAB		6/13/05	TAN	MONITORING WELL	TAN-25	218	1	1	1	1	1		1	1	1	D[2]	1	2								
RAA878	REG	GROUND WATER	GRAB		6/13/05	TAN	MONITORING WELL	TAN-26	389	1	1	1		1		1		1		1	2								
RAA879	REG/QC	GROUND WATER	DUP		6/13/05	TAN	MONITORING WELL	TAN-27	235	2	2	2	2	2				2		2	4								
RAA880	REG	GROUND WATER	GRAB		6/13/05	TAN	MONITORING WELL	TAN-28	240	1	1	1		1	1			1		D[1]	T[2]								
RAA881	REG	GROUND WATER	GRAB		6/13/05	TAN	MONITORING WELL	TAN-29	253	1	1	1		1	1			1		D[1]	T[2]								
RAA882	REG	GROUND WATER	GRAB		6/13/05	TAN	MONITORING WELL	TAN-30A	313	1	1	1	1	1				1		1	2								
RAA883	REG	GROUND WATER	GRAB		6/13/05	TAN	MONITORING WELL	TAN-31	258	1	1	1	1	1		1		1		1	2								
RAA884	REG	GROUND WATER	GRAB		6/13/05	TAN	MONITORING WELL	TAN-37A	240	1	1	1		1				1		1	2								
RAA885	REG	GROUND WATER	GRAB		6/13/05	TAN	MONITORING WELL	TAN-37B	270	1	1	1		1				1		1	2								
RAA886	REG	GROUND WATER	GRAB		6/13/05	TAN	MONITORING WELL	TAN-37C	375	1	1	1		1				1		1	2								
RAA887	REG	GROUND WATER	GRAB		6/13/05	TAN	MONITORING WELL	TAN-10A	233	1	1	1		1				1		1	2								
RAA888	REG	GROUND WATER	GRAB		6/13/05	TAN	MONITORING WELL	TAN-D2	241	1	1	1		1				1		1	2								
RAA889	REG	GROUND WATER	GRAB		6/13/05	TAN	MONITORING WELL	TAN-1859	250	1	1	1	1	1		1		1		1	2								

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

D - Double QC Volume T - Triple QC Volume

AT1: Alkalinity

AT2: Analysis Suite #1

AT3: Chemical Oxygen Demand

AT4: Dissolved Gases

AT5: Ethane/Ethene/Methane

AT6: Field Standard Addition - QC

AT7: Gamma Screen

AT8: Microbiological Analysis

AT9: Propionate/Butyrate/Acetate/Lactate - Filtered

AT10: Sr-90

AT11: Tritium

AT12: VOCs (CLP TAL)

AT13:

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

AED Sampling is included on Wells TSF-05A, TSF-05B, TAN-25, TAN-26, and TAN-31

Analysis Suites:

Analysis Suite #1: Ammonia Nitrogen, Phosphate, Sulfate, Iron (Inorganic Analysis)

Contingencies:

Sampling and Analysis Plan Table for Chemical and Radiological Analysis

06/06/2005 01:43 PM

Plan Table Number: INITIAL_JUNE05

SAP Number: INEEL/EXT-2002-00779

Sampler: Carroll, R. E.

Date: 06/02/2005 Plan Table Revision: 0.0 Project: OU 1-07B ISB RA GWM - INITIAL SEMI-ANNUAL JUNE 2005 Project Manager: NELSON, L. O. SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																				
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	A1	3A	C5	Y4	EG	F6	R5	MB	1N	RB	R8	VL								
RAA890	REG	GROUND WATER	GRAB		6/13/05	TAN	MONITORING WELL	TAN-1860	269	1	1	1		1				1		1	2								
RAA891	REG/QC	GROUND WATER	DUP		6/13/05	TAN	MONITORING WELL	TAN-1861	239	2	2	2	2	2				2		2	4								
RAA892	REG	GROUND WATER	GRAB		6/13/05	TAN	MONITORING WELL	TAN-09	293	1	1	1		1				1		1	2								
RAA893	QC	WATER	FBLK		6/13/05	TAN	FB - ISB	QC	NA	1	1	1	1	1				1		1	2								
RAA894	QC	WATER	FBLK		6/13/05	TAN	FB - ISB	QC	NA	1	1	1	1	1				1	1	1	2								
RAA895	QC	WATER	TBLK		6/13/05	TAN	TB - ISB	QC	NA				1	1							1								
RAA896	QC	WATER	TBLK		6/13/05	TAN	TB - ISB	QC	NA				1	1							1								
RAA897	QC	GROUND WATER	PE5		6/13/05	TAN	MONITORING WELL	TAN-2	240												1								
RAA898	QC	WATER	TBLK		6/13/05	TAN	TB - ISB	QC	NA												1								

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

D - Double QC Volume T - Triple QC Volume

AT1: Alkalinity

AT2: Analysis Suite #1

AT3: Chemical Oxygen Demand

AT4: Dissolved Gases

AT5: Ethane/Ethene/Methane

AT6: Field Standard Addition - QC

AT7: Gamma Screen

AT8: Microbiological Analysis

AT9: Propionate/Butyrate/Acetate/Lactate - Filtered

AT10: Sr-90

AT11: Tritium

AT12: VOCs (CLP TAL)

AT13:

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

AED Sampling is included on Wells TSF-05A, TSF-05B, TAN-25, TAN-26, and TAN-31

Analysis Suites:

Analysis Suite #1: Ammonia Nitrogen, Phosphate, Sulfate, Iron (Inorganic Analysis)

Contingencies:

Plan Table Number: ISB-AED-FY05

SAP Number: INEEL/EXT-2002-00779 Sampler: Carroll, R. E.

Date: 12/17/2004 Plan Table Revision: 4.0 Project: ISB ALTERNATE ELECTRON DONOR (AED) STUDY - FY-05 Project Manager: NELSON, L. O. SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																				
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	3A	C5	Y4	EG	MB	1N	VL	VM												
AED054	REG	GROUND WATER	GRAB		10/12/2004	TAN	MONITORING WELL	TSF-05A (71)	235	1	1	1	1		1	1													
AED055	REG	GROUND WATER	GRAB		10/12/2004	TAN	MONITORING WELL	TSF-05B (71)	270	1	1	1	1		1		1												
AED056	REG/QC	GROUND WATER	DUP		10/12/2004	TAN	MONITORING WELL	TAN-25 (1117)	218	2	2	2	2	1	2	2													
AED057	REG	GROUND WATER	GRAB		10/12/2004	TAN	MONITORING WELL	TAN-31 (1219)	258	1	1	1	1		1	1													
AED058	QC	WATER	FBLK		10/12/2004	TAN	FB - AED	QC	NA	1	1	1	1		1	1													
AED059	QC	WATER	TBLK		10/12/2004	TAN	TB - AED	QC	NA			1	1			1													
AED060	REG/QC	GROUND WATER	DUP		10/14/2004	TAN	MONITORING WELL	TSF-05A (71)	235	2	2	2	2		2	2													
AED061	REG	GROUND WATER	GRAB		10/14/2004	TAN	MONITORING WELL	TSF-05B (71)	270	1	1	1	1		1	1													
AED062	REG	GROUND WATER	GRAB		10/14/2004	TAN	MONITORING WELL	TAN-25 (1117)	218	1	1	1	1	1	1		1												
AED063	REG	GROUND WATER	GRAB		10/14/2004	TAN	MONITORING WELL	TAN-31 (1219)	258	1	1	1	1		1	1													
AED064	QC	WATER	FBLK		10/14/2004	TAN	FB - AED	QC	NA	1	1	1	1		1	1													
AED065	QC	WATER	TBLK		10/14/2004	TAN	TB - AED	QC	NA			1	1			1													
AED066	REG	GROUND WATER	GRAB		10/25/2004	TAN	MONITORING WELL	TSF-05A(71)	235	1	1	1	1		1		1												
AED067	REG	GROUND WATER	GRAB		10/25/2004	TAN	MONITORING WELL	TSF-05B(71)	270	1	1	1	1		1	1													
AED068	REG	GROUND WATER	GRAB		10/25/2004	TAN	MONITORING WELL	TAN-25(1117)	218	1	1	1	1	1	1	1													

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number. The complete sample identification number will appear on the sample labels.

AT1: Analysis Suite #1

AT2: Chemical Oxygen Demand

AT3: Dissolved Gases

AT4: Ethane/Ethene/Methane

AT5: Microbiological Analysis

AT6: Propionate/Butyrate/Acetate/Lactate

AT7: VOCs (CLP TAL)

AT8: VOCs (CLP TAL) - MS/MSD

AT9:

AT10:

AT11:

AT12:

AT13:

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, COD

Samples will be sent to IRC except Tritium and Strontium-90 which will be shipped to an off-site lab

The third duplicate, field blank, and trip blank will only be collected if needed

AED Sampling is included on Wells TSF-05A, TSF-05B, TSF-25, TSF-26, and TSF-31

Propionate/Butyrate/Acetate/Lactate - Lactate changed to Lactose

Dissolved Gases - Ethane/Ethene/Methane

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Plan Table Number: ISB-AED-FY05

SAP Number: INEEL/EXT-2002-00779 Sampler: Carroll, R. E.

Date: 12/17/2004 Plan Table Revision: 4.0 Project: ISB ALTERNATE ELECTRON DONOR (AED) STUDY - FY-05 Project Manager: NELSON, L. O. SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																			
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	3A	C5	Y4	EG	MB	1N	VL	VM												
AED069	REG/QC	GROUND WATER	DUP		10/25/2004	TAN	MONITORING WELL	TAN-31(1219)	258	2	2	2	2		2	2													
AED070	QC	WATER	FBLK		10/25/2004	TAN	FB-AED	FB-AED	NA	1	1	1	1		1	1													
AED071	QC	WATER	TBLK		10/25/2004	TAN	TB-AED	TB-AED	NA			1	1			1													
AED072	REG	GROUND WATER	GRAB		11/01/2004	TAN	MONITORING WELL	TSF-05A (71)	235	1	1	1	1		1	1													
AED073	REG	GROUND WATER	GRAB		11/01/2004	TAN	MONITORING WELL	TSF-05B (71)	270	1	1	1	1		1		1												
AED074	REG	GROUND WATER	GRAB		11/01/2004	TAN	MONITORING WELL	TAN-25 (1117)	218	1	1	1	1	1	1	1													
AED075	REG/QC	GROUND WATER	DUP		11/01/2004	TAN	MONITORING WELL	TAN-31 (1219)	258	2	2	2	2		2	2													
AED076	QC	WATER	FBLK		11/01/2004	TAN	FB - AED	QC	NA	1	1	1	1		1	1													
AED077	QC	WATER	TBLK		11/01/2004	TAN	TB - AED	QC	NA			1	1			1													
AED078	REG	GROUND WATER	GRAB		1/11/2005	TAN	MONITORING WELL	TSF-05A (71)	235	1	1	1	1		1	1													
AED079	REG	GROUND WATER	GRAB		1/11/2005	TAN	MONITORING WELL	TSF-05B (71)	270	1	1	1	1		1	1													
AED080	REG/QC	GROUND WATER	DUP		1/11/2005	TAN	MONITORING WELL	TAN-25 (1117)	218	2	2	2	2	1	2	2													
AED081	REG	GROUND WATER	GRAB		1/11/2005	TAN	MONITORING WELL	TAN-31 (1219)	258	1	1	1	1		1		1												
AED082	REG	GROUND WATER	GRAB		1/11/2005	TAN	MONITORING WELL	TAN-1859	250	1	1	1	1		1	1													
AED083	QC	WATER	FBLK		1/11/2005	TAN	FB - AED	QC	NA	1	1	1	1		1	1													

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

AT1: Analysis Suite #1

AT2: Chemical Oxygen Demand

AT3: Dissolved Gases

AT4: Ethane/Ethene/Methane

AT5: Microbiological Analysis

AT6: Propionate/Butyrate/Acetate/Lactate

AT7: VOCs (CLP TAL)

AT8: VOCs (CLP TAL) - MS/MSD

AT9:

AT10:

AT11:

AT12:

AT13:

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, COD

Samples will be sent to IRC except Tritium and Strontium-90 which will be shipped to an off-site lab

The third duplicate, field blank, and trip blank will only be collected if needed

AED Sampling is included on Wells TSF-05A, TSF-05B, TSF-25, TSF-26, and TSF-31

Propionate/Butyrate/Acetate/Lactate - Lactate changed to Lactose

Dissolved Gases - Ethane/Ethene/Methane

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Plan Table Number: ISB-AED-FY05

SAP Number: INEEL/EXT-2002-00779 Sampler: Carroll, R. E.

Date: 12/17/2004 Plan Table Revision: 4.0 Project: ISB ALTERNATE ELECTRON DONOR (AED) STUDY - FY-05 Project Manager: NELSON, L. O. SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																				
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	3A	CS	Y4	EG	MB	1N	VL	VM												
AED084	QC	WATER	TBLK		1/11/2005	TAB	TB - AED	QC	NA			1	1			1													
AED085	REG/QC	GROUND WATER	DUP		1/13/2005	TAN	MONITORING WELL	TSF-05A (71)	235	2	2	2	2		2	2													
AED086	REG	GROUND WATER	GRAB		1/13/2005	TAN	MONITORING WELL	TSF-05B (71)	270	1	1	1	1		1	1													
AED087	REG	GROUND WATER	GRAB		1/13/2005	TAN	MONITORING WELL	TAN-25 (1117)	218	1	1	1	1	1	1	1													
AED088	REG	GROUND WATER	GRAB		1/13/2005	TAN	MONITORING WELL	TAN-31 (1219)	258	1	1	1	1		1	1													
AED089	REG	GROUND WATER	GRAB		1/13/2005	TAN	MONITORING WELL	TAN-1859	250	1	1	1	1		1	1													
AED090	QC	WATER	FBLK		1/13/2005	TAN	FB - AED	QC	NA	1	1	1	1		1	1													
AED091	QC	WATER	TBLK		1/13/2005	TAN	TB - AED	QC	NA			1	1			1													
AED092	REG	GROUND WATER	GRAB		1/24/2005	TAN	MONITORING WELL	TSF-05A(71)	235	1	1	1	1		1	1													
AED093	REG/QC	GROUND WATER	DUP		1/24/2005	TAN	MONITORING WELL	TSF-05B(71)	270	2	2	2	2		2	2													
AED094	REG	GROUND WATER	GRAB		1/24/2005	TAN	MONITORING WELL	TAN-25(1117)	218	1	1	1	1	1	1	1													
AED095	REG	GROUND WATER	GRAB		1/24/2005	TAN	MONITORING WELL	TAN-31(1219)	258	1	1	1	1		1	1													
AED096	REG	GROUND WATER	GRAB		1/24/2005	TAN	MONITORING WELL	TAN-1859	250	1	1	1	1		1	1													
AED097	QC	WATER	FBLK		1/24/2005	TAN	FB - AED	QC	NA	1	1	1	1		1	1													
AED098	QC	WATER	FBLK		1/24/2005	TAN	TB - AED	QC	NA			1	1			1													

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

AT1: Analysis Suite #1

AT2: Chemical Oxygen Demand

AT3: Dissolved Gases

AT4: Ethane/Ethene/Methane

AT5: Microbiological Analysis

AT6: Propionate/Butyrate/Acetate/Lactate

AT7: VOCs (CLP TAL)

AT8: VOCs (CLP TAL) - MS/MSD

AT9:

AT10:

AT11:

AT12:

AT13:

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, COD

Samples will be sent to IRC except Tritium and Strontium-90 which will be shipped to an off-site lab

The third duplicate, field blank, and trip blank will only be collected if needed

AED Sampling is included on Wells TSF-05A, TSF-05B, TSF-25, TSF-26, and TSF-31

Propionate/Butyrate/Acetate/Lactate - Lactate changed to Lactose

Dissolved Gases - Ethane/Ethene/Methane

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Plan Table Number: ISB-AED-FY05

SAP Number: INEEL/EXT-2002-00779 Sampler: Carroll, R. E.

Date: 12/17/2004 Plan Table Revision: 4.0 Project: ISB ALTERNATE ELECTRON DONOR (AED) STUDY - FY-05 Project Manager: NELSON, L. O. SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																				
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	3A	C5	Y4	EG	MB	1N	VL	VM												
AED099	REG	GROUND WATER	GRAB		1/31/2005	TAN	MONITORING WELL	TSF-05A (71)	235	1	1	1	1		1		1											
AED100	REG/QC	GROUND WATER	DUP		1/31/2005	TAN	MONITORING WELL	TSF-05B (71)	270	2	2	2	2		2	2													
AED101	REG	GROUND WATER	GRAB		1/31/2005	TAN	MONITORING WELL	TAN-25 (1117)	218	1	1	1	1	1	1	1													
AED102	REG	GROUND WATER	GRAB		1/31/2005	TAN	MONITORING WELL	TAN-31 (1219)	258	1	1	1	1		1	1													
AED103	REG	GROUND WATER	GRAB		1/31/2005	TAN	MONITORING WELL	TAN-1859	250	1	1	1	1		1	1													
AED104	QC	WATER	FBLK		1/31/2005	TAN	FB - AED	QC	NA	1	1	1	1		1	1													
AED105	QC	WATER	TBLK		1/31/2005	TAN	TB - AED	QC	NA			1	1			1													
AED106	REG	GROUND WATER	GRAB		4/5/2005	TAN	MONITORING WELL	TSF-05A (71)	235	1	1	1	1		1	1													
AED107	REG/QC	GROUND WATER	DUP		4/5/2005	TAN	MONITORING WELL	TSF-05B (71)	270	2	2	2	2		2	2													
AED108	REG	GROUND WATER	GRAB		4/5/2005	TAN	MONITORING WELL	TAN-25 (1117)	218	1	1	1	1	1	1	1													
AED109	REG	GROUND WATER	GRAB		4/5/2005	TAN	MONITORING WELL	TAN-31 (1219)	258	1	1	1	1		1		1												
AED110	REG	GROUND WATER	GRAB		4/5/2005	TAN	MONITORING WELL	TAN-1859	250	1	1	1	1		1	1													
AED111	QC	WATER	FBLK		4/5/2005	TAN	FB - AED	QC	NA	1	1	1	1		1	1													
AED112	QC	WATER	TBLK		4/5/2005	TAN	TB - AED	QC	NA			1	1			1													
AED113	REG/QC	GROUND WATER	DUP		4/7/2005	TAN	MONITORING WELL	TSF-05A (71)	235	2	2	2	2		2	2													

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

AT1: Analysis Suite #1

AT2: Chemical Oxygen Demand

AT3: Dissolved Gases

AT4: Ethane/Ethene/Methane

AT5: Microbiological Analysis

AT6: Propionate/Butyrate/Acetate/Lactate

AT7: VOCs (CLP TAL)

AT8: VOCs (CLP TAL) - MS/MSD

AT9:

AT10:

AT11:

AT12:

AT13:

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, COD

Samples will be sent to IRC except Tritium and Strontium-90 which will be shipped to an off-site lab

The third duplicate, field blank, and trip blank will only be collected if needed

AED Sampling is included on Wells TSF-05A, TSF-05B, TSF-25, TSF-26, and TSF-31

Propionate/Butyrate/Acetate/Lactate - Lactate changed to Lactose

Dissolved Gases - Ethane/Ethene/Methane

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Plan Table Number: ISB-AED-FY05

SAP Number: INEEL/EXT-2002-00779

Sampler: Carroll, R. E.

Date: 12/17/2004 Plan Table Revision: 4.0 Project: ISB ALTERNATE ELECTRON DONOR (AED) STUDY - FY-05 Project Manager: NELSON, L. O. SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																				
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
										3A	C5	Y4	EG	MB	1N	VL	VM												
AED114	REG	GROUND WATER	GRAB		4/7/2005	TAN	MONITORING WELL	TSF-05B (71)	270	1	1	1	1		1	1													
AED115	REG	GROUND WATER	GRAB		4/7/2005	TAN	MONITORING WELL	TAN-25 (1117)	218	1	1	1	1	1	1	1													
AED116	REG	GROUND WATER	GRAB		4/7/2005	TAN	MONITORING WELL	TAN-31 (1219)	258	1	1	1	1		1	1													
AED117	REG	GROUND WATER	GRAB		4/7/2005	TAN	MONITORING WELL	TAN-1859	250	1	1	1	1		1	1													
AED118	QC	WATER	FBLK		4/7/2005	TAN	FB - AED	QC	NA	1	1	1	1		1	1													
AED119	QC	WATER	TBLK		4/7/2005	TAN	TB - AED	QC	NA			1	1			1													
AED120	REG	GROUND WATER	GRAB		4/18/2005	TAN	MONITORING WELL	TSF-05A(71)	235	1	1	1	1		1	1													
AED121	REG	GROUND WATER	GRAB		4/18/2005	TAN	MONITORING WELL	TSF-05B(71)	270	1	1	1	1		1		1												
AED122	REG	GROUND WATER	GRAB		4/18/2005	TAN	MONITORING WELL	TAN-25(1117)	218	1	1	1	1	1	1	1													
AED123	REG/QC	GROUND WATER	DUP		4/18/2005	TAN	MONITORING WELL	TAN-31(1218)	258	2	2	2	2		2	2													
AED124	REG	GROUND WATER	GRAB		4/18/2005	TAN	MONITORING WELL	TAN-1859	250	1	1	1	1		1	1													
AED125	QC	WATER	FBLK		4/18/2005	TAN	FB - AED	QC	NA	1	1	1	1		1	1													
AED126	QC	WATER	TBLK		4/18/2005	TAN	TB - AED	QC	NA			1	1			1													
AED127	REG	GROUND WATER	GRAB		4/25/2005	TAN	MONITORING WELL	TSF-05A(71)	235	1	1	1	1		1	1													
AED128	REG	GROUND WATER	GRAB		4/25/2005	TAN	MONITORING WELL	TSF-05B(71)	270	1	1	1	1		1		1												

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number. The complete sample identification number will appear on the sample labels.

AT1: Analysis Suite #1

AT2: Chemical Oxygen Demand

AT3: Dissolved Gases

AT4: Ethane/Ethene/Methane

AT5: Microbiological Analysis

AT6: Propionate/Butyrate/Acetate/Lactate

AT7: VOCs (CLP TAL)

AT8: VOCs (CLP TAL) - MS/MSD

AT9:

AT10:

AT11:

AT12:

AT13:

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, COD

Samples will be sent to IRC except Tritium and Strontium-90 which will be shipped to an off-site lab

The third duplicate, field blank, and trip blank will only be collected if needed

AED Sampling is included on Wells TSF-05A, TSF-05B, TSF-25, TSF-26, and TSF-31

Propionate/Butyrate/Acetate/Lactate - Lactate changed to Lactose

Dissolved Gases - Ethane/Ethene/Methane

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Plan Table Number: ISB-AED-FY05

SAP Number: INEEL/EXT-2002-00779 Sampler: Carroll, R. E.

Date: 12/17/2004 Plan Table Revision: 4.0 Project: ISB ALTERNATE ELECTRON DONOR (AED) STUDY - FY-05 Project Manager: NELSON, L. O. SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																				
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	3A	C5	Y4	EG	MB	1N	VL	VM												
AED129	REG	GROUND WATER	GRAB		4/25/2005	TAN	MONITORING WELL	TAN-25(1117)	218	1	1	1	1	1	1	1													
AED130	REG/QC	GROUND WATER	DUP		4/25/2005	TAN	MONITORING WELL	TAN-31(1218)	258	2	2	2	2		2	2													
AED131	REG	GROUND WATER	GRAB		4/25/2005	TAN	MONITORING WELL	TAN-1859	250	1	1	1	1		1	1													
AED132	QC	WATER	FBLK		4/25/2005	TAN	FB - AED	QC	NA	1	1	1	1		1	1													
AED133	QC	WATER	TBLK		4/25/2005	TAN	TB - AED	QC	NA			1	1			1													

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

AT1: Analysis Suite #1

AT2: Chemical Oxygen Demand

AT3: Dissolved Gases

AT4: Ethane/Ethene/Methane

AT5: Microbiological Analysis

AT6: Propionate/Butyrate/Acetate/Lactate

AT7: VOCs (CLP TAL)

AT8: VOCs (CLP TAL) - MS/MSD

AT9:

AT10:

AT11:

AT12:

AT13:

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, COD

Samples will be sent to IRC except Tritium and Strontium-90 which will be shipped to an off-site lab

The third duplicate, field blank, and trip blank will only be collected if needed

AED Sampling is included on Wells TSF-05A, TSF-05B, TSF-25, TSF-26, and TSF-31

Propionate/Butyrate/Acetate/Lactate - Lactate changed to Lactose

Dissolved Gases - Ethane/Ethene/Methane

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Sampling and Analysis Plan Table for Chemical and Radiological Analysis

02/14/2006 02:47 PM

Plan Table Number: ISB-AED-FEB05

SAP Number: INEEL/EXT-2002-00779

Sampler: Carroll, R. E.

Date: 02/02/2005 Plan Table Revision: 5.0 Project: ISB ALTERNATE ELECTRON DONOR (AED) STUDY - FY-05 Project Manager: NELSON, L. O. SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																				
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
										3A	Y4	EG	VL	VM															
AED106	REG	GROUND WATER	GRAB		2/28/2005	TAN	MONITORING WELL	TSF-05A	235	1	1	1	1																
AED107	REG/QC	GROUND WATER	DUP		2/28/2005	TAN	MONITORING WELL	TSF-05B	270	2	2	2	2																
AED108	REG	GROUND WATER	GRAB		2/28/2005	TAN	MONITORING WELL	TAN-25	218	1	1	1	1																
AED109	REG	GROUND WATER	GRAB		2/28/2005	TAN	MONITORING WELL	TAN-31	258	1	1	1		1															
AED110	REG	GROUND WATER	GRAB		2/28/2005	TAN	MONITORING WELL	TAN-1859	250	1	1	1	1																
AED111	QC	WATER	FBLK		2/28/2005	TAN	FB - AED	QC	NA	1	1	1	1																
AED112	QC	WATER	TBLK		2/28/2005	TAN	TB - AED	QC	NA		1	1	1																

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

D - Double QC Volume T - Triple QC Volume

AT1: Analysis Suite #1

AT2: Dissolved Gases

AT3: Ethane/Ethene/Methane

AT4: VOCs (CLP TAL)

AT5: VOCs (CLP TAL) - MS/MSD

AT6:

AT7:

AT8:

AT9:

AT10:

AT11:

AT12:

AT13:

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1, COD

Samples will be sent to IRC except Tritium and Strontium-90 which will be shipped to an off-site lab

The third duplicate, field blank, and trip blank will only be collected if needed

AED Sampling is included on Wells TSF-05A, TSF-05B, TSF-25, TAN-1859, and TSF-31

Dissolved Gases - Ethane/Ethene/Methane

Analysis Suites:

Analysis Suite #1: Sulfate, Iron (Inorganic Analysis)

Contingencies:

Sampling and Analysis Plan Table for Chemical and Radiological Analysis

02/14/2006 02:48 PM

Plan Table Number: ISB-AED-MAR05

SAP Number: INEEL/EXT-2002-00779

Sampler: Carroll, R. E.

Date: 02/25/2005 Plan Table Revision: 6.0 Project: ISB ALTERNATE ELECTRON DONOR (AED) STUDY - FY-05 Project Manager: NELSON, L. O. SMO Contact: KIRCHNER, D. R.

Sample Description						Sample Location				Enter Analysis Types (AT) and Quantity Requested																			
										AT1	AT2	AT3	AT4	AT5	AT6	AT7	AT8	AT9	AT10	AT11	AT12	AT13	AT14	AT15	AT16	AT17	AT18	AT19	AT20
Sampling Activity	Sample Type	Sample Matrix	Coll Type	Sampling Method	Planned Date	Area	Type of Location	Location	Depth (ft)	3A	Y4	EG	VL																
AED113	REG/QC	GROUND WATER	DUP		3/28/2005	TAN	MONITORING WELL	TSF-05A	235	2	2	2	2																
AED114	REG	GROUND WATER	GRAB		3/28/2005	TAN	MONITORING WELL	TSF-05B	270	1	1	1	1																
AED115	REG	GROUND WATER	GRAB		3/28/2005	TAN	MONITORING WELL	TAN-25	218	1	1	1	1																
AED116	REG	GROUND WATER	GRAB		3/28/2005	TAN	MONITORING WELL	TAN-31	258	1	1	1	1																
AED117	REG	GROUND WATER	GRAB		3/28/2005	TAN	MONITORING WELL	TAN-1859	250	1	1	1	1																
AED118	QC	WATER	FBLK		3/28/2005	TAN	FB - AED	QC	NA	1	1	1	1																
AED119	QC	WATER	TBLK		3/28/2005	TAN	TB - AED	QC	NA		1	1	1																

The sampling activity displayed on this table represents the first 6 to 9 characters of the sample identification number.

The complete sample identification number will appear on the sample labels.

D - Double QC Volume T - Triple QC Volume

AT1: Analysis Suite #1

AT2: Dissolved Gases

AT3: Ethane/Ethene/Methane

AT4: VOCs (CLP TAL)

AT5:

AT6:

AT7:

AT8:

AT9:

AT10:

AT11:

AT12:

AT13:

AT14:

AT15:

AT16:

AT17:

AT18:

AT19:

AT20:

Comments:

Field Tests - Analysis Suite #1

Samples will be sent to IRC

AED Sampling is included on Wells TSF-05A, TSF-05B, TSF-25, TAN-1859, and TSF-31

Dissolved Gases - Ethane/Ethene/Methane

Analysis Suites:

Analysis Suite #1: Hydrogen Ion (pH), Sulfate, Iron (Inorganic Analysis)

Contingencies:

Appendix B

AED Optimization Sampling Schedule

Appendix B

AED Optimization Sampling Schedule

Details of the high-frequency sampling conducted during the AED optimization are shown in Table B-1. For scheduling and data interpretation purposes, the day of the electron donor injection is labeled as Day 1. The date of each sampling event, name of each activity, "Day" after injection, monitoring location(s), and analyte set are detailed in Table B-1. Changes were made from the initial sampling schedule presented in the AED Optimization Plan (Harris and Hall 2004) to correspond with whey injection date changes. In addition, minor changes were made including:

- Addition of the "new" sampling method for E/E/M from October 2004-June 2005,
- Addition of TAN-1859 to the list of wells sampled at high-frequency from January-June 2005, and
- Simplification of the AED analysis set (to include only VOCs, dissolved gases, and redox indicators) from February 28, 2005-June 2005.

Table B-1. High-frequency sampling during the AED optimization.

Date(s)	Activity (Day)	Location	Analyte Set[a]
March 15, 2004	Sodium lactate injection 1X 6% (Day 1)	TSF-05	NA
March 16, 2004	Baseline groundwater monitoring (Day 2)	TSF-05A, TSF-05B, TAN-31	AED Analysis Set
		TAN-25	AED Analysis Set, MB
March 18, 2004	Baseline groundwater monitoring (Day 4)	TSF-05A, TSF-05B, TAN-31	AED Analysis Set
		TAN-25	AED Analysis Set, MB
March 22–24, 2004	ISB sampling, monthly (Days 8–10)	TAN-27, TAN-28, TAN-29, TAN-30A, TAN-37A, TAN-37B, TAN-37C, TAN-10A, TAN-D2, TAN-1860, and TAN-1861	AED Analysis Set, ^{3}H
		TAN-1859	AED Analysis Set, ^{3}H, and GS
		TSF-05A, TSF-05B, TAN-31, and TAN-26	AED Analysis Set, ^{3}H, ^{90}Sr, and GS
		TAN-25	AED Analysis Set, ^{3}H, ^{90}Sr, GS and MB
		TAN-25	AED Analysis Set, MB
April 5, 2004	Baseline groundwater monitoring (Day 22)	TSF-05A, TSF-05B, TAN-31	AED Analysis Set
April 19–20, 2004	ISB sampling, monthly (Days 36–37)	TAN-27, TAN-28, TAN-29, TAN-30A, TAN-37A, TAN-37B, TAN-37C, TAN-10A, TAN-D2, TAN-1860, and TAN-1861	AED Analysis Set, ^{3}H
		TAN-1859	AED Analysis Set, ^{3}H, and GS
		TSF-05A, TSF-05B, TAN-31, and TAN-26	AED Analysis Set, ^{3}H, ^{90}Sr, and GS
		TAN-25	AED Analysis Set, ^{3}H, ^{90}Sr, GS and MB
May 10, 2004	Sodium lactate injection 1X 6% (Day 1)	TSF-05	NA

Table B-1 (continued).

Date(s)	Activity (Day)	Location	Analyte Set[a]
May 11, 2004	Baseline groundwater monitoring (Day 2)	TSF-05A, TSF-05B, TAN-31	AED Analysis Set
		TAN-25	AED Analysis Set, MB
May 13, 2004	Baseline groundwater monitoring (Day 4)	TSF-05A, TSF-05B, TAN-31	AED Analysis Set
		TAN-25	AED Analysis Set, MB
May 17–19, 2004	ISB sampling, semiannual (Days 8–10)	TAN-27, TAN-28, TAN-29, TAN-30A, TAN-37A, TAN-37B, TAN-37C, TAN-10A, TAN-D2, TAN-1860, and TAN-1861	AED Analysis Set, ^{3}H, and SP
		TAN-1859	AED Analysis Set, ^{3}H, GS, and SP
		TSF-05A, TSF-05B, TAN-31, and TAN-26	AED Analysis Set, ^{3}H, ^{90}Sr, GS, and SP
		TAN-25	AED Analysis Set, ^{3}H, ^{90}Sr, GS, MB, and SP
June 1, 2004	Baseline groundwater monitoring (Day 23)[b]	TSF-05A, TSF-05B, TAN-31	AED Analysis Set
		TAN-25	AED Analysis Set, MB
June 14–16, 2004	ISB sampling, monthly (Days 36–38)	TAN-27, TAN-28, TAN-29, TAN-30A, TAN-37A, TAN-37B, TAN-37C, TAN-10A, TAN-D2, TAN-1860, and TAN-1861	AED Analysis Set, ^{3}H
		TAN-1859	AED Analysis Set, ^{3}H, and GS
		TSF-05A, TSF-05B, TAN-31, and TAN-26	AED Analysis Set, ^{3}H, ^{90}Sr, and GS
		TAN-25	AED Analysis Set, ^{3}H, ^{90}Sr, GS and MB

Table B-1 (continued).

Date(s)	Activity (Day)	Location	Analyte Set[a]
July 19–21, 2004	ISB sampling, monthly NPTF performance (Days 71–73)	TAN-27, TAN-28, TAN-29, TAN-30A, TAN-37A, TAN-37B, TAN-37C, TAN-10A, TAN-D2, TAN-1860, and TAN-1861	AED Analysis Set, ^{3}H
		TAN-1859	AED Analysis Set, ^{3}H, and GS
		TSF-05A, TSF-05B, TAN-31, and TAN-26	AED Analysis Set, ^{3}H, ^{90}Sr, and GS
		TAN-25	AED Analysis Set, ^{3}H, ^{90}Sr, GS, 9C, and MB
August 16, 2004	Whey injection #1 (Day 1)	TSF-05	NA
August 17, 2004	Groundwater monitoring (Day 2)	TSF-05A, TSF-05B, TAN-31	AED Analysis Set
		TAN-25	AED Analysis Set, MB
August 19, 2004	Groundwater monitoring (Day 4)	TSF-05A, TSF-05B, TAN-31	AED Analysis Set
		TAN-25	AED Analysis Set, MB
August 23–25, 2004	ISB sampling, quarterly (Days 8–10)	TAN-27, TAN-28, TAN-29, TAN-30A, TAN-37A, TAN-37B, TAN-37C, TAN-10A, TAN-D2, TAN-1860, and TAN-1861	AED Analysis Set, ^{3}H
		TAN-1859	AED Analysis Set, ^{3}H, and GS
		TSF-05A, TSF-05B, TAN-31, and TAN-26	AED Analysis Set, ^{3}H, ^{90}Sr, and GS
		TAN-25	AED Analysis Set, ^{3}H, ^{90}Sr, GS, and MB
September 7, 2004	Groundwater monitoring (Day 23)[c]	TSF-05A, TSF-05B, TAN-31	AED Analysis Set
		TAN-25	AED Analysis Set, MB

Table B-1 (continued).

Date(s)	Activity (Day)	Location	Analyte Set[a]
September 20–21, 2004	ISB sampling, monthly (Days 36–37)	TAN-27, TAN-28, TAN-29, TAN-30A, TAN-37A, TAN-37B, TAN-37C, TAN-10A, TAN-D2, TAN-1860, and TAN-1861	AED Analysis Set, ^{3}H
		TAN-1859	AED Analysis Set, ^{3}H, and GS
		TSF-05A, TSF-05B, TAN-31, and TAN-26	AED Analysis Set, ^{3}H, ^{90}Sr, and GS
		TAN-25	AED Analysis Set, ^{3}H, ^{90}Sr, GS, and MB
October 11, 2004	Whey injection #2 (Day 1)	TSF-05	NA
October 12, 2004	Groundwater monitoring (Day 2)[d]	TSF-05A, TSF-05B, and TAN-31	Revised AED Analysis Set
		TAN-25	Revised AED Analysis Set, MB
October 14, 2004	Groundwater monitoring (Day 4)	TSF-05A, TSF-05B, and TAN-31	Revised AED Analysis Set
		TAN-25	Revised AED Analysis Set, MB
October 18–20, 2004	ISB sampling, monthly (Days 8–10)	TAN-27, TAN-28, TAN-29, TAN-30A, TAN-37A, TAN-37B, TAN-37C, TAN-10A, TAN-D2, TAN-1860, and TAN-1861	AED Analysis Set, ^{3}H
		TAN-26	AED Analysis Set, ^{3}H, and GS
		TSF-05A, TSF-05B, TAN-31, and TAN-1859	Revised AED Analysis Set, ^{3}H, and GS
		TAN-25	Revised AED Analysis Set, ^{3}H, ^{90}Sr, GS, and MB
October 25, 2004	Groundwater monitoring (Day 15)	TSF-05A, TSF-05B, and TAN-31	Revised AED Analysis Set
		TAN-25	Revised AED Analysis Set, MB
November 1, 2004	Groundwater monitoring (Day 22)	TSF-05A, TSF-05B, and TAN-31	Revised AED Analysis Set
		TAN-25	Revised AED Analysis Set, MB

Table B-1 (continued).

Date(s)	Activity (Day)	Location	Analyte Set[a]
November 15–17, 2004	ISB sampling, semiannual (Days 36–38)	TAN-27, TAN-28, TAN-29, TAN-30A, TAN-37A, TAN-37B, TAN-37C, TAN-10A, TAN-D2, TAN-1860, and TAN-1861	AED Analysis Set, ^{3}H, and SP
		TAN-26	AED Analysis Set, ^{3}H, GS, and SP
		TSF-05A, TSF-05B, TAN-31, and TAN-1859	Revised AED Analysis Set, ^{3}H, GS, and SP
		TAN-25	Revised AED Analysis Set, ^{3}H, ^{90}Sr, GS, MB, and SP
December 13–14, 2004	ISB sampling, monthly (Days 64–65)	TAN-28, TAN-29, TAN-37A, TAN-37B, TAN-37C, TAN-10A, TAN-D2, TAN-1860, and TAN-1861	AED Analysis Set, ^{3}H
		TAN-27 and TAN-30A	Revised AED Analysis Set, ^{3}H
		TAN-26	AED Analysis Set, ^{3}H, and GS
		TSF-05A, TSF-05B, TAN-31, and TAN-1859	Revised AED Analysis Set, ^{3}H, and GS
		TAN-25	Revised AED Analysis Set, ^{3}H, ^{90}Sr, GS, and MB
January 10, 2005	Whey injection #3 (Day 1)	TSF-05	NA
January 11, 2005	Groundwater monitoring (Day 2)[e]	TSF-05A, TSF-05B, TAN-31, and TAN-1859	Revised AED Analysis Set
		TAN-25	Revised AED Analysis Set, MB
January 13, 2005	Groundwater monitoring (Day 4)	TSF-05A, TSF-05B, TAN-31, and TAN-1859	Revised AED Analysis Set
		TAN-25	Revised AED Analysis Set, MB

Table B-1 (continued).

Date(s)	Activity (Day)	Location	Analyte Set[a]
January 17–18, 2005	ISB sampling, monthly (Days 8–9)	TAN-28, TAN-29, TAN-37A, TAN-37B, TAN-37C, TAN-10A, TAN-D2, TAN-1860, and TAN-1861	AED Analysis Set, ^{3}H
		TAN-27 and TAN-30A	Revised AED Analysis Set, ^{3}H
		TAN-26	AED Analysis Set, ^{3}H, and GS
		TSF-05A, TSF-05B, TAN-31, and TAN-1859	Revised AED Analysis Set, ^{3}H, and GS
		TAN-25	Revised AED Analysis Set, ^{3}H, ^{90}Sr, GS, and MB
January 24, 2005	Groundwater monitoring (Day 15)	TSF-05A, TSF-05B, TAN-31, and TAN-1859	Revised AED Analysis Set
		TAN-25	Revised AED Analysis Set, MB
January 31, 2005	Groundwater monitoring (Day 22)	TSF-05A, TSF-05B, TAN-31, and TAN-1859	Revised AED Analysis Set
		TAN-25	Revised AED Analysis Set, MB
February 14–15, 2005	ISB sampling, monthly (Days 36–37)	TAN-28, TAN-29, TAN-37A, TAN-37B, TAN-37C, TAN-10A, TAN-D2, TAN-1860, and TAN-1861	AED Analysis Set, ^{3}H
		TAN-27 and TAN-30A	Revised AED Analysis Set, ^{3}H
		TAN-26	AED Analysis Set, ^{3}H, and GS
		TSF-05A, TSF-05B, TAN-31, and TAN-1859	Revised AED Analysis Set, ^{3}H, and GS
		TAN-25	Revised AED Analysis Set, ^{3}H, ^{90}Sr, GS, and MB
February 28, 2005	Groundwater monitoring (Day 50)[f]	TSF-05A, TSF-05B, TAN-31, and TAN-1859	Simplified AED Analysis Set, ^{3}H, and GS
		TAN-25	Simplified AED Analysis Set, ^{3}H, ^{90}Sr, GS, and MB

Table B-1 (continued).

Date(s)	Activity (Day)	Location	Analyte Set[a]
March 14–15, 2005	ISB sampling, monthly (Days 64–65)	TAN-28, TAN-29, TAN-37A, TAN-37B, TAN-37C, TAN-10A, TAN-D2, TAN-1860, and TAN-1861	AED Analysis Set, ^{3}H
		TAN-27 and TAN-30A	Revised AED Analysis Set, ^{3}H
		TAN-26	AED Analysis Set, ^{3}H, and GS
		TSF-05A, TSF-05B, TAN-31, and TAN-1859	Revised AED Analysis Set, ^{3}H, and GS
		TAN-25	Revised AED Analysis Set, ^{3}H, ^{90}Sr, GS, and MB
March 28–29, 2005	Groundwater monitoring (Days 78–79)	TSF-05A, TSF-05B, TAN-31, and TAN-1859	Simplified AED Analysis Set, ^{3}H, and GS
		TAN-25	Simplified AED Analysis Set, ^{3}H, ^{90}Sr, GS, and MB
April 11–12, 2005	ISB sampling, monthly (Days 92–93)	TAN-28, TAN-29, TAN-37A, TAN-37B, TAN-37C, TAN-10A, TAN-D2, TAN-1860, and TAN-1861	AED Analysis Set, ^{3}H
		TAN-27 and TAN-30A	Revised AED Analysis Set, ^{3}H
		TAN-26	AED Analysis Set, ^{3}H, and GS
		TSF-05A, TSF-05B, TAN-31, and TAN-1859	Revised AED Analysis Set, ^{3}H, and GS
		TAN-25	Revised AED Analysis Set, ^{3}H, ^{90}Sr, GS, and MB
April 25, 2005	Groundwater monitoring (Day 106)	TSF-05A, TSF-05B, TAN-31, and TAN-1859	Simplified AED Analysis Set, ^{3}H, and GS
		TAN-25	Simplified AED Analysis Set, ^{3}H, ^{90}Sr, GS, and MB

Table B-1 (continued).

Date(s)	Activity (Day)	Location	Analyte Set[a]
May 9–10, 2005	ISB sampling, monthly (Days 120–121)	TAN-28, TAN-29, TAN-37A, TAN-37B, TAN-37C, TAN-10A, TAN-D2, TAN-1860, and TAN-1861	AED Analysis Set, ^{3}H
		TAN-27 and TAN-30A	Revised AED Analysis Set, ^{3}H
		TAN-26	AED Analysis Set, ^{3}H, and GS
		TSF-05A, TSF-05B, TAN-31, and TAN-1859	Revised AED Analysis Set, ^{3}H, and GS
		TAN-25	Revised AED Analysis Set, ^{3}H, ^{90}Sr, GS, and MB
May 24, 2005	Groundwater monitoring (Day 135)	TSF-05A, TSF-05B, TAN-31, and TAN-1859	Simplified AED Analysis Set, ^{3}H, and GS
		TAN-25	Simplified AED Analysis Set, ^{3}H, ^{90}Sr, GS, and MB
June 14–16, 2005	ISB sampling, monthly (Days 156–158)	TAN-28, TAN-29, TAN-37A, TAN-37B, TAN-37C, TAN-10A, TAN-D2, TAN-1860, and TAN-1861	AED Analysis Set, ^{3}H
		TAN-27 and TAN-30A	Revised AED Analysis Set, ^{3}H
		TAN-26	AED Analysis Set, ^{3}H, and GS
		TSF-05A, TSF-05B, TAN-31, and TAN-1859	Revised AED Analysis Set, ^{3}H, and GS
		TAN-25	Revised AED Analysis Set, ^{3}H, ^{90}Sr, GS, and MB

a. The analyte set key is provided in Table B-2.
b. Sampling postponed 1 day due to Memorial Day Holiday.
c. Sampling postponed 1 day due to Labor Day Holiday.
d. The "new" sampling method for dissolved gases implemented.
e. TAN-1859 added to the list of AED sampling wells to be sampled at the higher frequency sampling for the AED optimization.
f. The AED analyte list simplified to only sample for VOCs, dissolved gases (both "new" and "old' method), and redox indicators.

Table B-2. Key for analyte sets shown in Table B-1.

Analyte Set Code	Analytes
AED Analysis Set	Sodium lactate electron donor constituents (lactate, propionate, butyrate, acetate) or whey powder electron donor constituents (lactose, propionate, butyrate, acetate, isobutyrate, isovalerate, valerate, hexanoate, formate), COD, VOCs (PCE, TCE, cis-DCE, trans-DCE, VC), and dissolved gases (E/E/M), redox indicators (sulfate, iron, pH, ORP)
Revised AED Analysis Set	Sodium lactate electron donor constituents (lactate, propionate, butyrate, acetate) or whey powder electron donor constituents (lactose, propionate, butyrate, acetate, isobutyrate, isovalerate, valerate, hexanoate, formate), COD, VOCs (PCE, TCE, cis-DCE, trans-DCE, VC), and dissolved gases (E/E/M), dissolved gases “new sampling method” (E/E/M), redox indicators (sulfate, iron, pH, ORP)
Simplified AED Analysis Set	VOCs (PCE, TCE, cis-DCE, trans-DCE, VC), and dissolved gases (E/E/M), dissolved gases “new sampling method” (E/E/M), redox indicators (sulfate, iron, pH, ORP)
MB	Microbial parameters (DNA)
90Sr	Sr-90
3H	Tritium
GS	Gamma screen
SP	VOC splits (off-site lab)
9C	Research sample
NA	No samples collected

Appendix C

Quality Assurance Details for the AED Optimization

Appendix C

Quality Assurance Details for the AED Optimization

C-1. IN SITU BIOREMEDIATION DATA QUALITY ASSURANCE

General quality assurance (QA) requirements are established in the *Quality Assurance Project Plan for Waste Area Groups 1, 2, 3, 4, 5, 6, 7, 10, and Deactivation, Decontamination, and Decommissioning* (QAPjP)(DOE-ID 2004). Specific accuracy, precision, and completeness requirements for this reporting period are defined in the In Situ Bioremediation Remedial Action Groundwater Monitoring Plan for Test Area North, Operable Unit 1-07B (GWMP)(INEEL 2003) and current supporting documents. Duplicates, field blanks, and trip blanks are used as specified in the QAPjP (DOE-ID 2004). Results for accuracy, precision, and completeness are provided in this appendix.

All data collected during this reporting period were to be used to monitor performance of the AED optimization; thus, no single sample was critical to the interpretation. The quality level defined for all sampling activities in this plan was screening data in accordance with the QAPjP; however, the GWMP stated that most of the quality assurance/quality control (QA/QC) elements required for definitive data were to be used. The GWMP further stated that definitive confirmation was to be provided for the volatile organic compound (VOC) data and the ethene/ethane/methane (E/E/M) data by sending splits to an off-site laboratory. Definitive data underwent Level A validation by the INL Sample and Analysis Management (SAM) Program. All other data from off-site laboratories received completeness and quality control (QC) checks.

C-1.1 Accuracy

Accuracy is a measure of bias in the sampling and analysis program. It can be affected by the methods used for sampling preservation and handling, by the sample matrix, and by analytical methods. During this reporting period, accuracy was assessed through analysis of standards, standard additions, splits, performance evaluation (PE) samples, blanks, and matrix spike and matrix spike duplicate (MS/MSD) data.

Standards—Standards were used to determine the accuracy of analyses conducted in the ISB field laboratory, including chemical oxygen demand (COD), sulfate, iron, phosphate, and ammonia. A COD standard was analyzed with each set of COD samples during this reporting period. Standards for sulfate, iron, phosphate, and ammonia were analyzed each day the analyses were conducted. Table C-1 presents accuracy results for standards, including the type of analyte, the date the standard was analyzed, the standard and observed concentration, recovery percentages, target recovery percentages, and whether the target recovery criteria were met. Target recovery percentages are stated in TPR-166, "In Situ Bioremediation Field Laboratory Procedure." The corrective action for standards reported outside of the target range is to repeat the standard once (except COD). If the recovery is still not within the target range, then the data will be flagged and a procedural review will be performed to determine where in the process the error is being introduced. Percent recovery was calculated as:

$$\%\ Recovery = \frac{Observed\ Value}{Standard\ Value}\ x\ 100\% \qquad \text{(C-1)}$$

where:

Observed Value = result of analysis

Standard Value = value of standard solution.

The target recovery was met for COD during 19 of 35 sampling events during the AED optimization. With the exception of the September 7, 2004, COD sample, the standards that were outside of the range were all biased high and had a relative percent difference (RPD) of <8% when compared to each other. The failed COD standards all came from the same lot number and were precise but were not accurate. Therefore, in January 2005 new COD standard solution was ordered, and two COD standards were prepared: one COD standard was prepared with 1 mL of sulfuric acid, and the other was prepared without sulfuric acid. Acidifying the COD standards yielded COD standard target recoveries that were more accurate. Therefore, the COD standard prepared on January 31, 2005, was acidified with sulfuric acid, and each subsequent COD standard was prepared with 1 mL of sulfuric acid for the remainder of the AED optimization. The remainder of the COD standards were all within the target recovery range.

For sulfate, the target recovery was met on 57 of 61 sampling days. The sulfate standard was not performed on May 9 or 10, 2005, due to a limited supply of the sulfate reagent packets; therefore, the sulfate reagent packets were used for the samples instead of the standards. For iron, the target recovery was met on 61 of 62 sampling days during the AED optimization. For phosphate, the target recovery was met on all nine sampling days. For ammonia, the target recovery was met on seven of the nine sampling days. The target recovery was not met for one sampling day and the standard was not repeated. A high range ammonia standard was run on June 15, 2005, because all AED wells were above the low range detection limit. The target recovery was not met for the high range standard.

Table C-1. Accuracy of ISB field laboratory standards.

Analyte	Standard Date	Standard (mg/L)	Observed (mg/L)	Recovery (%)	Target Recovery (%)	Criteria Met?
COD	03/18/04	800	902	113	90-110	No
COD	03/23/04	800	868	109	90-110	Yes
COD	03/24/04	800	876	110	90-110	Yes
COD	04/05/04	800	929	116	90-110	No
COD	04/21/04	800	870	109	90-110	Yes
COD	05/13/04	800	957	120	90-110	No
COD	05/19/04	800	878	110	90-110	Yes
COD	06/01/04	800	890	111	90-110	No
COD	06/16/04	800	891	111	90-110	No
COD	07/21/04	800	962	120	90-110	No
COD	08/17/04	800	878	110	90-110	Yes
COD	08/19/04	800	837	105	90-110	Yes
COD	08/24/04	800	888	111	90-110	No
COD	08/25/04	800	919	115	90-110	No
COD	09/07/04	800	224	28	90-110	No
COD	09/22/04	800	796	100	90-110	Yes

Table C-1. (continued).

Analyte	Standard Date	Standard (mg/L)	Observed (mg/L)	Recovery (%)	Target Recovery (%)	Criteria Met?
COD	10/12/04	800	884	111	90-110	No
COD	10/14/04	800	857	107	90-110	Yes
COD	10/20/04	800	860	108	90-110	Yes
COD	10/25/04	800	818	102	90-110	Yes
COD	11/01/04	800	968	121	90-110	No
COD	11/17/04	800	937	117	90-110	No
COD	12/15/04	800	929	116	90-110	No
COD	01/11/05	800	927	116	90-110	No
COD	01/13/05	800	864	108	90-110	Yes
COD	01/18/05[a]	800	785	98	90-110	Yes
COD	01/18/05	800	891	111	90-110	No
COD	01/24/05[a]	800	827	103	90-110	Yes
COD	01/24/05	800	919	115	90-110	No
COD	01/31/05[b]	800	813	102	90-110	Yes
COD	02/16/05	800	821	103	90-110	Yes
COD	03/16/05	800	832	104	90-110	Yes
COD	04/13/05	800	851	106	90-110	Yes
COD	05/11/05	800	853	107	90-110	Yes
COD	06/16/05	800	845	106	90-110	Yes
Sulfate	03/16/04	50	45	90	90-110	Yes
Sulfate	03/18/04	50	46	92	90-110	Yes
Sulfate	03/22/04	50	48	96	90-110	Yes
Sulfate	03/23/04	50	46	92	90-110	Yes
Sulfate	03/23/04	50	47	94	90-110	Yes
Sulfate	03/24/04	50	46	92	90-110	Yes
Sulfate	03/24/04	50	45	90	90-110	Yes
Sulfate	04/05/04	50	48	96	90-110	Yes
Sulfate	04/19/04	50	45	90	90-110	Yes
Sulfate	04/20/04	50	49	98	90-110	Yes
Sulfate	05/11/04	50	44/42	88	90-110	No[e]
Sulfate	05/13/04	50	39/46	78	90-110	No/Yes[e]
Sulfate	05/17/04	50	49	98	90-110	Yes
Sulfate	05/18/04	50	47	94	90-110	Yes

Table C-1. (continued).

Analyte	Standard Date	Standard (mg/L)	Observed (mg/L)	Recovery (%)	Target Recovery (%)	Criteria Met?
Sulfate	05/19/04	50	48	96	90-110	Yes
Sulfate	06/01/04	50	46	92	90-110	Yes
Sulfate	06/14/04	50	49	98	90-110	Yes
Sulfate	06/15/04	50	50	100	90-110	Yes
Sulfate	06/16/04	50	50	100	90-110	Yes
Sulfate	07/19/04	50	48	96	90-110	Yes
Sulfate	07/20/04	50	49	98	90-110	Yes
Sulfate	07/21/04	50	48	96	90-110	Yes
Sulfate	08/17/04	50	48	96	90-110	Yes
Sulfate	08/19/04	50	46	92	90-110	Yes
Sulfate	08/23/04	50	48	96	90-110	Yes
Sulfate	08/24/04	50	49	98	90-110	Yes
Sulfate	08/25/04	50	45	90	90-110	Yes
Sulfate	09/07/04	50	42/42	84	90-110	No/No [f]
Sulfate	09/20/04	50	52	104	90-110	Yes
Sulfate	09/21/04	50	49	98	90-110	Yes
Sulfate	10/12/04	50	49	98	90-110	Yes
Sulfate	10/14/04	50	51	102	90-110	Yes
Sulfate	10/18/04	50	50	100	90-110	Yes
Sulfate	10/19/04	50	49	98	90-110	Yes
Sulfate	10/25/04	50	53	106	90-110	Yes
Sulfate	11/01/04	50	49	98	90-110	Yes
Sulfate	11/15/04	50	53	106	90-110	Yes
Sulfate	11/16/04	50	55	110	90-110	Yes
Sulfate	11/17/04	50	55	110	90-110	Yes
Sulfate	12/13/04	50	54	108	90-110	Yes
Sulfate	12/14/04	50	52	104	90-110	Yes
Sulfate	01/11/05	50	53	106	90-110	Yes
Sulfate	01/13/05	50	51	102	90-110	Yes
Sulfate	01/17/05	50	52	104	90-110	Yes
Sulfate	01/18/05	50	53	106	90-110	Yes
Sulfate	01/24/05	50	52	104	90-110	Yes
Sulfate	01/31/05	50	52	104	90-110	Yes

Table C-1. (continued).

Analyte	Standard Date	Standard (mg/L)	Observed (mg/L)	Recovery (%)	Target Recovery (%)	Criteria Met?
Sulfate	02/14/05	50	51	102	90-110	Yes
Sulfate	02/15/05	50	53	106	90-110	Yes
Sulfate	02/28/05	50	54	108	90-110	Yes
Sulfate	03/14/05	50	50	100	90-110	Yes
Sulfate	03/15/05	50	54	108	90-110	Yes
Sulfate	03/28/05	50	53	106	90-110	Yes
Sulfate	03/29/05	50	53	106	90-110	Yes
Sulfate	04/11/05	50	58	116	90-110	No
Sulfate	04/12/05	50	58	116	90-110	No
Sulfate	04/13/05	50	51	102	90-110	Yes
Sulfate	04/25/05	50	54	108	90-110	Yes
Sulfate	05/24/05	50	55	110	90-110	Yes
Sulfate	06/14/05	50	55	110	90-110	Yes
Sulfate	06/15/05	50	55	110	90-110	Yes
Iron	03/16/04	1.00	0.95	95	75-125	Yes
Iron	03/18/04	1.00	0.97	97	75-125	Yes
Iron	03/22/04	1.00	1.09	109	75-125	Yes
Iron	03/23/04	1.00	0.99	99	75-125	Yes
Iron	03/24/04	1.00	0.98	98	75-125	Yes
Iron	04/05/04	1.00	0.97	97	75-125	Yes
Iron	04/19/04	1.00	0.61	61	75-125	No
Iron	04/20/04	1.00	1.00	100	75-125	Yes
Iron	05/11/04	1.00	1.16	116	75-125	Yes
Iron	05/13/04	1.00	1.13	113	75-125	Yes
Iron	05/17/04	1.00	0.19/0.96	96	75-125	No/Yes
Iron	05/18/04	1.00	1.06	106	75-125	Yes
Iron	05/19/04	1.00	0.91	91	75-125	Yes
Iron	06/01/04	1.00	0.99	99	75-125	Yes
Iron	06/14/04	1.00	0.93	93	75-125	Yes
Iron	06/15/04	1.00	0.99	99	75-125	Yes
Iron	06/16/04	1.00	1.11	111	75-125	Yes
Iron	07/19/04	1.00	0.95	95	75-125	Yes
Iron	07/20/04	1.00	1.06	106	75-125	Yes

Table C-1. (continued).

Analyte	Standard Date	Standard (mg/L)	Observed (mg/L)	Recovery (%)	Target Recovery (%)	Criteria Met?
Iron	07/21/04	1.00	0.95	95	75-125	Yes
Iron	08/17/04	1.00	1.09	109	75-125	Yes
Iron	08/19/04	1.00	1.07	107	75-125	Yes
Iron	08/23/04	1.00	1.05	105	75-125	Yes
Iron	08/24/04	1.00	1.02	102	75-125	Yes
Iron	08/25/04	1.00	1.07	107	75-125	Yes
Iron	09/07/04	1.00	1.01	101	75-125	Yes
Iron	09/20/04	1.00	0.96	96	75-125	Yes
Iron	09/21/04	1.00	1.00	100	75-125	Yes
Iron	10/12/04	1.00	1.01	101	75-125	Yes
Iron	10/14/04	1.00	1.03	103	75-125	Yes
Iron	10/18/04	1.00	1.04	104	75-125	Yes
Iron	10/19/04	1.00	1.00	100	75-125	Yes
Iron	10/25/04	1.00	1.07	107	75-125	Yes
Iron	11/01/04	1.00	1.02	102	75-125	Yes
Iron	11/15/04	1.00	1.10	110	75-125	Yes
Iron	11/16/04	1.00	1.09	109	75-125	Yes
Iron	11/17/04	1.00	1.21	121	75-125	Yes
Iron	12/13/04	1.00	0.97	97	75-125	Yes
Iron	12/14/04	1.00	0.98	98	75-125	Yes
Iron	01/11/05	1.00	1.06	106	75-125	Yes
Iron	01/13/05	1.00	1.06	106	75-125	Yes
Iron	01/17/05	1.00	1.03	103	75-125	Yes
Iron	01/18/05	1.00	1.06	106	75-125	Yes
Iron	01/24/05	1.00	1.02	102	75-125	Yes
Iron	01/31/05	1.00	1.06	106	75-125	Yes
Iron	02/14/05	1.00	1.01	101	75-125	Yes
Iron	02/15/05	1.00	1.09	109	75-125	Yes
Iron	02/28/05	1.00	1.06	106	75-125	Yes
Iron	03/14/05	1.00	1.06	106	75-125	Yes
Iron	03/15/05	1.00	1.01	101	75-125	Yes
Iron	03/28/05	1.00	1.13	113	75-125	Yes
Iron	03/29/05	1.00	1.00	100	75-125	Yes

Table C-1. (continued).

Analyte	Standard Date	Standard (mg/L)	Observed (mg/L)	Recovery (%)	Target Recovery (%)	Criteria Met?
Iron	04/11/05	1.00	0.81	81	75-125	Yes
Iron	04/12/05	1.00	0.77	77	75-125	Yes
Iron	04/13/05	1.00	0.81	81	75-125	Yes
Iron	04/13/05[c]	1.00	0.99	99	75-125	Yes
Iron	04/25/05	1.00	0.90	90	75-125	Yes
Iron	05/09/05	1.00	0.90	90	75-125	Yes
Iron	05/10/05	1.00	0.96	96	75-125	Yes
Iron	05/23/05	1.00	0.90	90	75-125	Yes
Iron	06/14/05	1.00	1.00	100	75-125	Yes
Iron	06/15/05	1.00	0.98	98	75-125	Yes
Phosphate	05/17/04	2.00	2.01	101	90-110	Yes
Phosphate	05/18/04	1.00	1.09	109	90-110	Yes
Phosphate	05/19/04	2.00	2.10	105	90-110	Yes
Phosphate	11/15/04	2.00	2.20	110	90-110	Yes
Phosphate	11/16/04	2.00	2.06	103	90-110	Yes
Phosphate	11/17/04	2.00	2.14	107	90-110	Yes
Phosphate	06/14/05	2.00	2.20	110	90-110	Yes
Phosphate	06/15/05	2.00	2.04	102	90-110	Yes
Ammonia	05/17/04	1.00	1.07	107	90-110	Yes
Ammonia	05/18/04	1.00	1.01	101	90-110	Yes
Ammonia	05/19/04	1.00	0.97	97	90-110	Yes
Ammonia	11/15/04	1.00	1.02	102	90-110	Yes
Ammonia	11/16/04	1.00	0.76	76	90-110	No
Ammonia	11/17/04	1.00	0.99	99	90-110	Yes
Ammonia	06/14/05	1.00	1.09	109	90-110	Yes
Ammonia	06/15/05	1.00	1.08	108	90-110	Yes
Ammonia[d]	06/15/05	5	4	80	90-110	No

a. In January 2005 two COD standards were prepared. One COD standard was acidified with 1 mL of sulfuric acid and the other standard prepared without sulfuric acid in order to try to obtain more accurate COD standard target recoveries.
b. Beginning on January 31, 2005 the COD standard was acidified with 1 mL of sulfuric acid, and each subsequent COD standard was acidified in the same manner through the end of the AED optimization.
c. Added 0.502 grams of RoVer powder to the 1.00 mg/L iron standard prepared on March 28, 2005 to obtain better target recovery results.
d. An ammonia high range standard (0-50 mg/L) run on 06/15/05 because the AED wells were all above the low range detection limit.
e. Colorimeter recalibrated on May 13, 2004, to correct out of range readings.
f. New bottle unsealed 9/7/2004.

Standard Additions—Standard additions (matrix spikes) were used to determine the accuracy of analyses conducted in the ISB field laboratory. Standard additions of sulfate, alkalinity, phosphate, and ammonia were conducted once during the each AED optimization sampling event. A sulfate standard concentration of 1,000 mg/L was used to perform standard additions (Table C-2). All but one sulfate standard addition were within the target recovery percentage range. For alkalinity standard additions, 0.1 mg/L of a 0.500 N alkalinity standard solution and a titrant with a concentration of 1.600 N H_2SO_4 were used to perform three standard additions (Table C-3). For alkalinity, the standard addition target recovery was met for two or all three of the standard additions performed per sampling day. Standard solutions with concentrations of 50 mg/L were used for both phosphate (Table C-4) and ammonia (Table C-5). All phosphate and ammonia standard additions were within the target recovery percentage range. Percent recovery was calculated using Equation 1.

Table C-2. Accuracy of ISB field laboratory standard additions for sulfate.

Sulfate Standard Date	Sample (mg/L)	Added Volume (mL)	Actual (mg/L)	Observed (mg/L)	Recovery (%)	Target Recovery (%)	Criteria Met?
03/23/04	31	0.1	41	40	98	75-125	Yes
		0.2	51	49	96	75-125	Yes
		0.3	61	56	92	75-125	Yes
03/23/04	37	0.1	47	48	102	75-125	Yes
		0.2	57	56	98	75-125	Yes
		0.3	67	66	99	75-125	Yes
04/19/04	41	0.1	51	49	96	75-125	Yes
05/19/04	47	0.1	57	58	102	75-125	Yes
06/15/04	12	0.1	22	25	114	75-125	Yes
07/19/03	41	0.1	51	49	96	75-125	Yes
08/24/04	38	0.1	48	46	96	75-125	Yes
09/20/04	41	0.1	51	50	98	75-125	Yes
10/18/04	42	0.1	52	51	98	75-125	Yes
10/19/04	41	0.1	51	57	112	75-125	Yes
11/17/04	45	0.2	65	71	109	75-125	Yes
12/14/04	41	0.2	61	67	110	75-125	Yes
01/17/05	45	0.2	65	66	102	75-125	Yes
02/14/05	45	0.2	65	70	108	75-125	Yes
02/14/05	51	0.2	71	71	100	75-125	Yes
03/14/05	45	0.2	65	68	105	75-125	Yes
03/15/05	45	0.2	65	69	106	75-125	Yes
04/11/05	44	0.2	64	68	106	75-125	Yes
04/12/05	47	0.2	67	65	97	75-125	Yes
05/10/05	31	0.2	51	72	141	75-125	No
05/11/05	44	0.2	64	68	106	75-125	Yes
06/14/05	43	0.2	63	66	105	75-125	Yes
06/15/05	48	0.2	68	63	93	75-125	Yes

Table C-3. Accuracy of ISB field laboratory standard additions for alkalinity.

Alkalinity Standard Date	Titration Range (mg/L)	Sample (mg/L)	Theoretical Endpoint (digits)	Observed Endpoint (digits)	Recovery (%)	Target Recovery (%)	Criteria Met?
03/23/04	100-400	248	25	24	96	90-110	Yes
			25	24	96	90-110	Yes
			25	24	96	90-110	Yes
04/19/04	100-400	234	25	26	104	90-110	Yes
			25	25	100	90-110	Yes
			25	27	108	90-110	Yes
05/19/04	100-400	236	25	27	108	90-110	Yes
			25	24	96	90-110	Yes
			25	25	100	90-110	Yes
06/15/04	100-400	334	25	25	100	90-110	Yes
			25	23	92	90-110	Yes
			25	23	92	90-110	Yes
07/19/04	100-400	191	25	25	100	90-110	Yes
			25	24	96	90-110	Yes
			25	25	100	90-110	Yes
08/24/04	100-400	248	25	27	108	90-110	Yes
			25	28	112	90-110	No
			25	25	100	90-110	Yes
09/20/04	100-400	240	25	27	108	90-110	Yes
			25	22	88	90-110	Yes
			25	25	100	90-110	Yes
10/18/04	100-400	250	25	25	100	90-110	Yes
			25	26	104	90-110	Yes
			25	24	96	90-110	Yes
10/19/04	100-400	238	25	25	100	90-110	Yes
			25	26	104	90-110	Yes
			25	25	100	90-110	Yes
11/17/04	100-400	252	25	26	104	90-110	Yes
			25	27	108	90-110	Yes
			25	25	100	90-110	Yes
12/14/04	100-400	271	25	25	100	90-110	Yes
			25	24	96	90-110	Yes
			25	23	92	90-110	Yes

Table C-3. (continued).

Alkalinity Standard Date	Titration Range (mg/L)	Sample (mg/L)	Theoretical Endpoint (digits)	Observed Endpoint (digits)	Recovery (%)	Target Recovery (%)	Criteria Met?
01/17/05	100-400	237	25	27	108	90-110	Yes
			25	25	100	90-110	Yes
			25	25	100	90-110	Yes
02/14/05	100-400	220	25	25	100	90-110	Yes
			25	25	100	90-110	Yes
			25	22	88	90-110	Yes
02/14/05	200-800	450	25	24	96	90-110	Yes
			25	25	100	90-110	Yes
			25	23	92	90-110	Yes
03/14/05	200-800	576	25	28	112	90-110	No
			25	26	104	90-110	Yes
			25	24	96	90-110	Yes
03/15/05	100-400	244	25	25	100	90-110	Yes
			25	23	92	90-110	Yes
			25	26	104	90-110	Yes
04/11/05	100-400	367	25	26	104	90-110	Yes
			25	26	104	90-110	Yes
			25	24	96	90-110	Yes
04/12/05	100-400	252	25	23	92	90-110	Yes
			25	27	108	90-110	Yes
			25	25	100	90-110	Yes
05/09/05	100-400	215	25	24	96	90-110	Yes
			25	25	100	90-110	Yes
			25	24	96	90-110	Yes
06/14/05	100-400	195	25	26	104	90-110	Yes
			25	26	104	90-110	Yes
			25	26	104	90-110	Yes

Table C-4. Accuracy of ISB field laboratory standard additions for phosphate.

Phosphate Standard Date	Sample (mg/L)	Added Volume (mL)	Theoretical (mg/L)	Observed (mg/L)	Recovery (%)	Target Recovery (%)	Criteria Met?
05/19/04	0.60	0.1	1.00	0.95	95	75-125	Yes
11/17/04	0.19	0.4	0.59	0.68	115	75-125	Yes
06/14/05	0.63	0.4	1.03	1.28	124	75-125	Yes
06/15/05	0.42	0.2	0.62	0.60	97	75-125	Yes

Table C-5. Accuracy of ISB field laboratory standard additions for ammonia.

Ammonia Standard Date	Sample (mg/L)	Added Volume (mg/L)	Theoretical (mg/L)	Observed (mg/L)	Recovery (%)	Target Recovery (%)	Criteria Met?
05/19/04	0.07	0.4	0.47	0.39	83	75-125	Yes
11/17/04	0	0.4	0.4	0.41	103	75-125	Yes
06/14/05	0.59	0.4	0.99	0.90	91	75-125	Yes
06/15/05	0.17	0.4	0.57	0.58	102	75-125	Yes

Splits—During the AED optimization, VOC splits were collected in May 2004, November 2004, and June 2005. Split samples consisted of a VOC sample sent to the INEEL Research Center (IRC) and a VOC sample sent to an off-site laboratory for definitive confirmation. The off-site laboratories used Environmental Protection Agency (EPA) Method 8260B (EPA 1996) for independent verification of the IRC solid-phase microextraction (SPME) results. The off-site and IRC split data for VOCs (Table C-6) are presented with the RPD calculated between the two results. The RPD is calculated as:

$$RPD = \frac{|C_1 - C_2|}{\left[\frac{C_1 + C_2}{2}\right]} \times 100\% \qquad \text{(C-2)}$$

where:

C_1, C_2 = analyte concentrations determined for duplicate or split samples.

Percentages of split samples with RPDs less than 25%, less than 50%, and greater than 50% are shown in Table C-7. RPDs were not calculated when IRC results were reported as not detected or trace and are not included in Table C-7, as was the case for all PCE splits. RPDs were calculated using off-site laboratory results that had been flagged as an estimated or undetected value.

All TCE and trans-DCE split samples fell below 25% RPD. Cis-DCE split samples had 5 out of 11 samples greater than 50% RPD. VC split samples had 4 out of 10 samples greater than 50% RPD. Split samples do not provide a way to determine which laboratory is reporting the more accurate results; therefore, performance evaluation (PE) results and duplicate samples were examined for both laboratories to determine individual accuracy and precision at both the on-site and off-site laboratories.

Table C-6. Relative percent differences for VOC split analyses.

Well	Date	Off-Site PCE (µg/L)	Flag	IRC PCE (µg/L)	RPD (%)	Off-Site TCE (µg/L)	Flag	IRC TCE (µg/L)	RPD (%)	Off-Site trans-DCE (µg/L)	Flag	IRC trans-DCE (µg/L)	RPD (%)	Off-Site cis-DCE (µg/L)	Flag	IRC cis-DCE (µg/L)	RPD (%)	Off-Site VC (µg/L)	Flag	IRC VC (µg/L)	RPD (%)
TSF-05A	05/17/04	25	U	ND	NA	34	J	30.2	11.8	330		269.5	20.2	150		159.0	5.8	84		51.7	47.6
TSF-05A	11/15/04	5	U	ND	NA	5	U	<10	NA	180		188.9	4.8	24		20.9	13.8	28		40.2	35.8
TSF-05A	06/14/05	5	U	<10	NA	5	U	<10	NA	86		92.7	7.5	3	J	<10	NA	10	U	ND	NA
TSF-05B	05/18/04	5	U	ND	NA	8		<10	NA	220		208.8	5.2	27		133.9	132.9	14		17.1	19.9
TSF-05B	11/16/04	5	U	ND	NA	5	U	<10	NA	220	D	185.1	17.2	44		61.2	32.7	28		30.7	9.2
TSF-05B	06/15/05	5	U	<10	NA	57		51.5	10.1	150		155.6	3.7	48		43.5	9.8	17		35.7	40.7
TAN-25	05/18/04	5	U	ND	NA	7		<10	NA	170		153.9	9.9	5		82.3	177.1	6		<10	NA
TAN-25	11/16/04	5	U	ND	NA	1	J	<10	NA	110		137.2	22.0	2	J	<10	NA	2	J	3.6	57.1
TAN-25	11/16/04	5	U	ND	NA	2	J	<10	NA	130		136.7	5.0	2	J	<10	NA	2		3.9	64.4
TAN-25	06/15/05	5	U	ND	NA	5	U	<10	NA	130		146.3	11.8	1	J	<10	NA	10	U	6.6	41
TAN-31	05/18/04	5	U	<10	NA	2	J	<10	NA	150		177.0	16.5	1	J	15.6	175.9	2	U	<10	NA
TAN-31	05/18/04	5	UJ	<10	NA	2	J	<10	NA	150	J	169.0	11.9	2	J	14.6	151.8	2	UJ	<10	NA
TAN-31	11/16/04	5	U	ND	NA	5	U	<10	NA	130		120.9	7.3	5	U	<10	NA	10	U	5	NA
TAN-31	6/15/05	5	U	ND	NA	5	U	<10	NA	98		103.4	5.4	3	J	<10	NA	2	J	6.6	107
TAN-1859	05/18/04	5	U	ND	NA	5	J	<10	NA	200		207.1	3.5	14		17.9	24.5	5		<10	NA
TAN-1859	11/16/04	5	U	ND	NA	2	J	<10	NA	140		175.2	22.3	9		27.8	102.2	3		5.9	65.2
TAN-1859	6/15/05	5	U	ND	NA	8		<10	NA	250	D	278.2	10.7	21		16.1	26.4	5		ND	NA

Table C-7. Percentages of RPDs for split analyses.

Analyte	Percentage of Samples with <25% RPD	Percentage of Samples with <50% RPD	Percentage of Samples with >50% RPD
TCE	100	100	0
trans-DCE	100	100	0
cis-DCE	36	55	45
VC	20	60	40

Performance Evaluation Samples—PE samples were analyzed for VOCs using the SPME method at the IRC and the EPA 8260B method (EPA 1996) at an off-site laboratory. During this reporting period, the off-site laboratory was Lionville Laboratory, Inc. The PE program was administered by the INEEL SAM using commercially supplied certified standards. PE samples were purchased and prepared by Environmental Resource Associates and shipped directly from this vendor to the INEEL ISB Field Team. Field team members included the PE samples with the other ISB samples collected during that sampling event, which were all sent together to the IRC and Lionville Laboratory, Inc.

During this reporting period, PE samples were sent monthly to the IRC for both high (>100 ppb) and low (<100 ppb) range VOC concentrations. Three PE samples (one low range in November 2004, two high range in May 2004 and June 2005) were sent to Lionville Laboratory, Inc. for analysis. Tables C-8 and C-9 present the results for the SPME method. Table C-10 presents the results for the EPA 8260B method. These tables include the analyte type, dates of analysis, certified concentrations, observed concentrations, accepted performance limits established by Environmental Resource Associates, and whether the observed concentration falls within the accepted performance limits. For the IRC (using the SPME method), the majority of samples fell within the accepted performance limits for both low and high range VOC samples (Table C-9). For the off-site laboratory (using the EPA 8260B method), all results fell within the accepted performance limits (Table C-10); however, only 15 PE analyses were run at the offsite laboratory compared to 255 PE analyses run at the IRC.

Table C-8. IRC SPME performance evaluation results.

Analyte	Date	Certified (µg/L)	Observed (µg/L)	Accepted Performance Limits (µg/L)	Within Accepted Performance Limits?
PCE	March-04	0.0	<10 (ND)	NA	NA
PCE	March-04	0.0	<10 (ND)	NA	NA
PCE	March-04	56.6	50.3	36.6–68.7	Yes
PCE	March-04	56.6	48.6	36.6–68.7	Yes
PCE	April-04	83.0	71.9	53.8–99.5	Yes
PCE	April-04	83.0	72.9	53.8–99.5	Yes
PCE	April-04	800	611.0	518–958	Yes
PCE	April-04	800	612.5	518–958	Yes
PCE	May-04	15.8	14.1	10.2–18.9	Yes
PCE	May-04	15.8	13.6	10.2–18.9	Yes
PCE	May-04	524	326.0	339–628	No

Table C-8. (continued).

Analyte	Date	Certified (µg/L)	Observed (µg/L)	Accepted Performance Limits (µg/L)	Within Accepted Performance Limits?
PCE	May-04	524	333.4	339–628	No
PCE	June-04	12.3	11.2	7.96–14.7	Yes
PCE	June-04	12.3	10.1	7.96–14.7	Yes
PCE	June-04	191	161.1	123–228	Yes
PCE	June-04	191	169.4	123–228	Yes
PCE	July-04	31.7	26.9	20.5–38.0	Yes
PCE	July-04	31.7	31.4	20.5–38.0	Yes
PCE	July-04	442	336.6	286–530	Yes
PCE	July-04	442	347.9	286–530	Yes
PCE	August-04	0.0	<10 (ND)	NA	NA
PCE	August-04	0.0	<10 (ND)	NA	NA
PCE	August-04	937	488.9	607–1120	No
PCE	August-04	937	527.7	607–1120	No
PCE	September-04	13.8	7.2 (<10)	8.91–16.5	No
PCE	September-04	13.8	8.2 (<10)	8.91–16.5	No
PCE	September-04	420	301.2	272–504	Yes
PCE	September-04	420	289.9	272–504	Yes
PCE	October-04	55.3	52.3	35.8–66.2	Yes
PCE	October-04	55.3	49.5	35.8–66.2	Yes
PCE	October-04	0.00	<10 (ND)	NA	NA
PCE	October-04	0.00	<10 (ND)	NA	NA
PCE	November-04	90.3	78.8	58.5–108	Yes
PCE	November-04	90.3	78.4	58.5–108	Yes
PCE	November-04	691	631.5	448–828	Yes
PCE	November-04	691	633.8	448–828	Yes
PCE	December-04	74.5	59.0	48.2–89.3	Yes
PCE	December-04	74.5	57.7	48.2–89.3	Yes
PCE	December-04	654	442.7	423–783	Yes
PCE	December-04	654	395.2	423–783	Yes
PCE	January-05	84.1	87.9	54.4–101	Yes
PCE	January-05	84.1	86.6	54.4–101	Yes
PCE	January-05	221	181.9	143–265	Yes
PCE	January-05	221	181.2	143–265	Yes
PCE	February-05	0.00	<10 (ND)	NA	NA
PCE	February-05	0.00	<10 (ND)	NA	NA

Table C-8. (continued).

Analyte	Date	Certified (µg/L)	Observed (µg/L)	Accepted Performance Limits (µg/L)	Within Accepted Performance Limits?
PCE	February-05	317	227.4	209–380	Yes
PCE	February-05	317	281.8	206–380	Yes
PCE	March-05	30.8	28.7	20.0–36.9	Yes
PCE	March-05	30.8	28.6	20.0–36.9	Yes
PCE	March-05	596	482.0	388–714	Yes
PCE	April-05	54.2	52.0	35.3–65.0	Yes
PCE	April-05	54.2	53.8	35.3–65.0	Yes
PCE	April-05	780	620.9	508–936	Yes
PCE	May-05	72.1	55.1	46.9–86.4	Yes
PCE	May-05	72.1	56.5	46.9–86.4	Yes
PCE	May-05	144	128.0	93.7–173	Yes
PCE	June-05	0	<10 (ND)	NA	NA
PCE	June-05	691	392.4	450–828	No
PCE	June-05	691	392.5	450–828	No
TCE	March-04	0.00	<10 (ND)	NA	NA
TCE	March-04	0.00	<10 (ND)	NA	NA
TCE	March-04	21.2	20.5	15.2–25.9	Yes
TCE	March-04	21.2	20.1	15.2–25.9	Yes
TCE	April-04	91.3	87.7	65.4–111	Yes
TCE	April-04	91.3	84.5	65.4–111	Yes
TCE	April-04	543	453.1	389–662	Yes
TCE	April-04	543	454.5	389–662	Yes
TCE	May-04	30.9	28.3	22.1–37.7	Yes
TCE	May-04	30.9	26.4	22.1–37.7	Yes
TCE	May-04	900	572.3	645–1100	No
TCE	May-04	900	595.6	645–1100	No
TCE	June-04	11.3	10.3	8.13–13.8	Yes
TCE	June-04	11.3	9.8	8.13–13.8	Yes
TCE	June-04	123	112.6	88.4–150	Yes
TCE	June-04	123	116.4	88.4–150	Yes
TCE	July-04	39.2	42.3	28.1–47.8	Yes
TCE	July-04	39.2	41.3	28.1–47.8	Yes
TCE	July-04	332	301.2	238–405	Yes
TCE	July-04	332	301.9	238–405	Yes

Table C-8. (continued).

Analyte	Date	Certified (µg/L)	Observed (µg/L)	Accepted Performance Limits (µg/L)	Within Accepted Performance Limits?
TCE	August-04	0.00	<10 (ND)	NA	NA
TCE	August-04	0.00	<10 (ND)	NA	NA
TCE	August-04	254	196.9	182–310	Yes
TCE	August-04	254	215.9	182–310	Yes
TCE	September-04	26.8	28.1	19.2–32.7	Yes
TCE	September-04	26.8	25.2	19.2–32.7	Yes
TCE	September-04	138	120.2	99.0–169	Yes
TCE	September-04	138	111.9	99.0–169	Yes
TCE	October-04	85.5	97.3	61.3–104	Yes
TCE	October-04	85.5	85.3	61.3–104	Yes
TCE	October-04	0.00	<10 (ND)	NA	NA
TCE	October-04	0.00	<10 (ND)	NA	NA
TCE	November-04	48.3	48.0	34.6–58.9	Yes
TCE	November-04	48.3	45.5	34.6–58.9	Yes
TCE	November-04	125	127.8	89.4–152	Yes
TCE	November-04	125	123.9	89.4–152	Yes
TCE	December-04	90.5	84.4	64.9–110	Yes
TCE	December-04	90.5	76.3	64.9–110	Yes
TCE	December-04	704	536.7	505–859	Yes
TCE	December-04	704	472.8	505–859	Yes
TCE	January-05	41.2	44.6	29.5–50.3	Yes
TCE	January-05	41.2	46.3	29.5–50.3	Yes
TCE	January-05	402	374.0	288–490	Yes
TCE	January-05	402	371.6	288–490	Yes
TCE	February-05	0.00	<10 (ND)	NA	NA
TCE	February-05	0.00	<10 (ND)	NA	NA
TCE	February-05	704	726.8	508–854	Yes
TCE	February-05	704	728.5	508–854	Yes
TCE	March-05	65.4	64.9	47.2–79.3	Yes
TCE	March-05	65.4	55.3	47.2–79.3	Yes
TCE	March-05	116	97.6	83.5–140	Yes
TCE	April-05	26.5	28.0	19.1–32.1	Yes
TCE	April-05	26.5	31.6	19.1–32.1	Yes
TCE	April-05	141	130.4	102–171	Yes
TCE	May-05	55.3	48.7	39.9–67.1	Yes

Table C-8. (continued).

Analyte	Date	Certified (µg/L)	Observed (µg/L)	Accepted Performance Limits (µg/L)	Within Accepted Performance Limits?
TCE	May-05	55.3	46.8	39.9–67.1	Yes
TCE	May-05	493	470.7	356–598	Yes
TCE	June-05	0.00	<10 (ND)	NA	NA
TCE	June-05	125	99.5	90.3–152	Yes
TCE	June-05	125	101	90.3–152	Yes
cis-DCE	March-04	0.00	<10 (ND)	NA	NA
cis-DCE	March-04	0.00	<10 (ND)	NA	NA
cis-DCE	March-04	33.9	35.8	25.7–42.0	Yes
cis-DCE	March-04	33.9	35.5	25.7–42.0	Yes
cis-DCE	April-04	27.1	20.2	20.6–33.6	No
cis-DCE	April-04	27.1	23.2	20.6–33.6	Yes
cis-DCE	April-04	727	587.5	551–899	Yes
cis-DCE	April-04	727	584.4	551–899	Yes
cis-DCE	May-04	82.5	83.0	62.6–102	Yes
cis-DCE	May-04	82.5	77.0	62.6–102	Yes
cis-DCE	May-04	619	311.6	470–766	No
cis-DCE	May-04	619	330.7	470–766	No
cis-DCE	June-04	92.1	78.7	69.9–114	Yes
cis-DCE	June-04	92.1	84.3	69.9–114	Yes
cis-DCE	June-04	407	354.4	309–504	Yes
cis-DCE	June-04	407	365.9	309–504	Yes
cis-DCE	July-04	11.6	<10 (ND)	8.82–14.4	No
cis-DCE	July-04	11.6	<10 (ND)	8.82–14.4	No
cis-DCE	July-04	111	98.9	84.6–138	Yes
cis-DCE	July-04	111	100.9	84.6–138	Yes
cis-DCE	August-04	0.00	<10 (ND)	NA	NA
cis-DCE	August-04	0.00	<10 (ND)	NA	NA
cis-DCE	August-04	499	455.6	379–618	Yes
cis-DCE	August-04	499	484.6	379–618	Yes
cis-DCE	September-04	71.7	92.4	54.4–88.7	No
cis-DCE	September-04	71.7	80.1	54.4–88.7	Yes
cis-DCE	September-04	336	307.7	255–416	Yes
cis-DCE	September-04	336	282.3	255–416	Yes
cis-DCE	October-04	19.9	13.4	15.1–24.6	No

Table C-8. (continued).

Analyte	Date	Certified (µg/L)	Observed (µg/L)	Accepted Performance Limits (µg/L)	Within Accepted Performance Limits?
cis-DCE	October-04	19.9	13.9	15.1–24.6	No
cis-DCE	October-04	0.00	<10 (ND)	NA	NA
cis-DCE	October-04	0.00	<10 (ND)	NA	NA
cis-DCE	November-04	87.3	90.1	66.2–108	Yes
cis-DCE	November-04	87.3	87.4	66.2–108	Yes
cis-DCE	November-04	324	336.2	246–401	Yes
cis-DCE	November-04	324	333.2	246–401	Yes
cis-DCE	December-04	36.8	31.5	27.9–45.6	Yes
cis-DCE	December-04	36.8	30.2	27.9–45.6	Yes
cis-DCE	December-04	330	225.8	250–408	No
cis-DCE	December-04	330	210.6	250–408	No
cis-DCE	January-05	50.9	67.5	38.6–63.0	No
cis-DCE	January-05	50.9	68.9	38.6–63.0	No
cis-DCE	January-05	504	466.6	382–623	Yes
cis-DCE	January-05	504	464.9	382–623	Yes
cis-DCE	February-05	0.00	<10 (ND)	NA	NA
cis-DCE	February-05	0.00	<10 (ND)	NA	NA
cis-DCE	February-05	446	456.2	346–550	Yes
cis-DCE	February-05	446	452.6	346–550	Yes
cis-DCE	March-05	29.4	29.3	22.8–36.3	Yes
cis-DCE	March-05	29.4	29.2	22.8–36.3	Yes
cis-DCE	March-05	147	144.8	114–181	Yes
cis-DCE	April-05	38.4	39.4	29.8–47.2	Yes
cis-DCE	April-05	38.4	44.3	29.8–47.2	Yes
cis-DCE	April-05	366	362.4	284–450	Yes
cis-DCE	May-05	56.7	54.4	43.9–69.9	Yes
cis-DCE	May-05	56.7	54.6	43.9–69.9	Yes
cis-DCE	May-05	605	586.7	469–746	Yes
cis-DCE	June-05	0.00	<10 (ND)	NA	NA
cis-DCE	June-05	324	291.5	251–399	Yes
cis-DCE	June-05	324	289.7	251–399	Yes
trans-DCE	March-04	0.00	<10 (ND)	NA	NA
trans-DCE	March-04	0.00	<10 (ND)	NA	NA
trans-DCE	March-04	15.8	14.8	11.3–19.9	Yes

Table C-8. (continued).

Analyte	Date	Certified (µg/L)	Observed (µg/L)	Accepted Performance Limits (µg/L)	Within Accepted Performance Limits?
trans-DCE	March-04	15.8	15.7	11.3–19.9	Yes
trans-DCE	April-04	43.9	44.0	31.6–55.5	Yes
trans-DCE	April-04	43.9	44.0	31.6–55.5	Yes
trans-DCE	April-04	153	126.5	110–193	Yes
trans-DCE	April-04	153	127.3	110–193	Yes
trans-DCE	May-04	65.9	68.8	47.4–83.2	Yes
trans-DCE	May-04	65.9	63.1	47.4–83.2	Yes
trans-DCE	May-04	900	478.3	648–1104	No
trans-DCE	May-04	900	503.9	648–1104	No
trans-DCE	June-04	86.0	89.5	61.9–109	Yes
trans-DCE	June-04	86.0	88.1	61.9–109	Yes
trans-DCE	June-04	373	342.4	268–470	Yes
trans-DCE	June-04	373	346.9	268–470	Yes
trans-DCE	July-04	21.5	20.8	15.5–27.1	Yes
trans-DCE	July-04	21.5	21.6	15.5–27.1	Yes
trans-DCE	July-04	478	447.5	344–603	Yes
trans-DCE	July-04	478	448.7	344–603	Yes
trans-DCE	August-04	0.00	<10 (ND)	NA	NA
trans-DCE	August-04	0.00	<10 (ND)	NA	NA
trans-DCE	August-04	139	136.4	100–176	Yes
trans-DCE	August-04	139	144.7	100–176	Yes
trans-DCE	September-04	57.3	72.9	41.3–72.4	No
trans-DCE	September-04	57.3	65.1	41.3–72.4	Yes
trans-DCE	September-04	802	680.6	578–1010	Yes
trans-DCE	September-04	802	626.7	578–1010	Yes
trans-DCE	October-04	35.3	39.3	25.4–44.6	Yes
trans-DCE	October-04	35.3	35.4	25.4–44.6	Yes
trans-DCE	October-04	0.00	<10 (ND)	NA	NA
trans-DCE	October-04	0.00	<10 (ND)	NA	NA
trans-DCE	November-04	55.4	57.6	39.9–70.0	Yes
trans-DCE	November-04	55.4	55.6	39.9–70.0	Yes
trans-DCE	November-04	218	221.1	157–275	Yes
trans-DCE	November-04	218	217.5	157–275	Yes
trans-DCE	December-04	52.5	50.9	37.8–66.3	Yes
trans-DCE	December-04	52.5	47.9	37.8–66.3	Yes

Table C-8. (continued).

Analyte	Date	Certified (µg/L)	Observed (µg/L)	Accepted Performance Limits (µg/L)	Within Accepted Performance Limits?
trans-DCE	December-04	478	340.0	344–603	No
trans-DCE	December-04	478	316.9	344–603	No
trans-DCE	January-05	34.4	34.8	24.8–43.4	Yes
trans-DCE	January-05	34.4	35.9	24.8–43.4	Yes
trans-DCE	January-05	611	402.2	440–771	No
trans-DCE	January-05	611	400.5	440–771	No
trans-DCE	February-05	0.00	<10 (ND)	NA	NA
trans-DCE	February-05	0.00	<10 (ND)	NA	NA
trans-DCE	February-05	153	146.9	111–192	Yes
trans-DCE	February-05	153	146.2	111–192	Yes
trans-DCE	March-05	44.9	50.8	32.6–56.5	Yes
trans-DCE	March-05	44.9	51.5	32.6–56.5	Yes
trans-DCE	March-05	296	301.4	215–373	Yes
trans-DCE	April-05	80.2	93.4	58.2–101	Yes
trans-DCE	April-05	80.2	100.1	58.2–101	Yes
trans-DCE	April-05	246	265.9	178–310	Yes
trans-DCE	May-05	31.7	26.2	23.0–39.9	Yes
trans-DCE	May-05	31.7	26.3	23.0–39.9	Yes
trans-DCE	May-05	461	421.2	335–580	Yes
trans-DCE	June-05	0.00	<10 (ND)	NA	NA
trans-DCE	June-05	218	201.2	158–274	Yes
trans-DCE	June-05	218	203	157–274	Yes
VC	March-04	0.00	<10 (ND)	NA	NA
VC	March-04	0.00	<10 (ND)	NA	NA
VC	March-04	88.0	151.4	47.2–138	No
VC	March-04	88.0	166.4	47.2–138	No
VC	April-04	41.0	51.4	22.0–64.2	Yes
VC	April-04	41.0	60.6	22.0–64.2	Yes
VC	April-04	115	100.9	61.7–180	Yes
VC	April-04	115	104.0	61.7–180	Yes
VC	May-04	75.4	79.0	40.5–118	Yes
VC	May-04	75.4	77.8	40.5–118	Yes
VC	May-04	188	52.5	101–294	No
VC	May-04	188	53.0	101–294	No

Table C-8. (continued).

Analyte	Date	Certified (µg/L)	Observed (µg/L)	Accepted Performance Limits (µg/L)	Within Accepted Performance Limits?
VC	June-04	18.5	25.0	9.9–29.0	Yes
VC	June-04	18.5	25.3	9.9–29.0	Yes
VC	June-04	400	349.0	215–626	Yes
VC	June-04	400	343.9	215–626	Yes
VC	July-04	22.0	44.6	11.8–34.4	No
VC	July-04	22.0	42.7	11.8–34.4	No
VC	July-04	220	211.6	118–344	Yes
VC	July-04	220	212.0	118–344	Yes
VC	August-04	0.00	<10 (ND)	NA	NA
VC	August-04	0.00	<10 (ND)	NA	NA
VC	August-04	210	176.5	113–330	Yes
VC	August-04	210	205.8	113–330	Yes
VC	September-04	65.6	121.3	35.2–103	No
VC	September-04	65.6	122.5	35.2–103	No
VC	September-04	118	62.9	63.1–184	No
VC	September-04	118	61.8	63.1–184	No
VC	October-04	28.0	48.5	15.0–43.8	No
VC	October-04	28.0	46.8	15.0–43.8	No
VC	October-04	0.00	<10 (ND)	NA	NA
VC	October-04	0.00	<10 (ND)	NA	NA
VC	November-04	30.0	41.3	16.1–47.0	Yes
VC	November-04	30.0	38.9	16.1–47.0	Yes
VC	November-04	397	311.0	213–621	Yes
VC	November-04	397	321.1	213–621	Yes
VC	December-04	56.0	74.0	30.0–87.7	Yes
VC	December-04	56.0	71.2	30.0–87.7	Yes
VC	December-04	500	288.4	268–783	Yes
VC	December-04	500	252.9	268–783	No
VC	January-05	72.0	123.2	38.6–113	No
VC	January-05	72.0	128.3	38.6–113	No
VC	January-05	620	313.1	333–970	No
VC	January-05	620	309.2	333–970	No
VC	February-05	0.00	<10 (ND)	NA	NA
VC	February-05	0.00	<10 (ND)	NA	NA
VC	February-05	184	167.3	98.6–284	Yes

Table C-8. (continued).

Analyte	Date	Certified (µg/L)	Observed (µg/L)	Accepted Performance Limits (µg/L)	Within Accepted Performance Limits?
VC	February-05	184	176.7	98.6–284	Yes
VC	March-05	33.0	63.3	17.7–50.9	No
VC	March-05	33.0	63.5	17.7–50.9	No
VC	March-05	110	142.8	58.9–170	Yes
VC	April-05	25.2	27.8	13.5–38.8	Yes
VC	April-05	25.2	27.7	13.5–38.8	Yes
VC	April-05	448	385.6	240–690	Yes
VC	May-05	47.0	71.0	25.2–72.5	Yes
VC	May-05	47.0	71.1	25.2–72.5	Yes
VC	May-05	300	235.2	161–463	Yes
VC	June-05	0.00	<10 (ND)	NA	NA
VC	June-05	397	322	213–613	Yes
VC	June-05	397	320.1	213–613	Yes

Table C-9. Summary of IRC performance evaluation sample results.

Analyte	Number/Percentage of Low Range Samples within Accepted Performance Limits	Number/Percentage of High Range Samples within Accepted Performance Limits
PCE	24 of 26 samples 92%	19 of 25 samples 76%
TCE	26 of 26 samples 100%	23 of 25 samples 92%
cis-DCE	18 of 26 samples 69%	21 of 25 samples 84%
trans-DCE	25 of 26 samples 96%	19 of 25 samples 76%
VC	14 of 26 samples 54%	17 of 25 samples 68%

Table C-10. EPA 8260B performance evaluation sample results from Lionville Laboratory, Inc.

Analyte	Date	Certified (µg/L)	Observed (µg/L)	Accepted Performance Limits (µg/L)	Within Accepted Performance Limits?
PCE	May-04	413	360	268–495	Yes
PCE	November-04	45.2	46.0	29.2–54.1	Yes
PCE	June-05	259	260	169–311	Yes
TCE	May-04	710	610	509–867	Yes
TCE	November-04	22.1	23	15.9–27.0	Yes
TCE	June-05	543	490	392–659	Yes
cis-DCE	May-04	489	440	370–604	Yes
cis-DCE	November-04	32.0	35	24.3–39.6	Yes
cis-DCE	June-05	441	410	342–543	Yes
trans-DCE	May-04	711	630	512–897	Yes
trans-DCE	November-04	66.9	71	48.1–84.4	Yes
trans-DCE	June-05	615	520	447–774	Yes
VC	May-04	149.0	160	79.8–233	Yes
VC	November-04	21.0	19	11.3–32.9	Yes
VC	June-05	176	160	94.3–272	Yes

Blanks—The GWMP (INEEL 2003) requirements include collecting one trip blank per sample cooler that contains samples to be analyzed for VOCs or E/E/M samples and one field blank per 20 samples (or one sample per day if number of monitoring locations is <20) for all analytes. For the blanks collected during this reporting period, no significant detections were reported, with the exception of methane in the field blanks and trip blanks. These detections consistently ranged between 100 and 200 mg/L beginning with the June 14, 2004, sampling event and continuing throughout the AED optimization. Methane is detected in the blanks due to the calibration range of the analytical method used at the IRC. Since high methane concentrations are detected in TAN source area wells, the IRC analyst has the calibration range for methane set for best accuracy at high concentrations. However, this limits the accuracy of low methane concentrations and results in false reported detections in the blanks.

Matrix Spike and Matrix Spike Duplicate—Laboratory QA requirements for MS/MSD data percent recovery are between 71 to 120% (INEEL 2003). IRC MS/MSD data are shown in Tables C-11 and C-12 and off-site laboratory data are listed in Table C-13. For the IRC (using the SPME method), the majority of samples met the percent recovery requirements (Table C-11). Off-site laboratory MS/MSD data were only reported for TCE and the target percent recovery was met for 5 of 6 off-site recoveries. The percent recovery of the MS/MSD is calculated as shown below:

$$Recovery\,(\%) = \frac{Ci - Co}{Ct}\ x\ 100\% \qquad \text{(C-3)}$$

where:

Ci = measured concentration of spiked aliquot

Co = measured concentration of unspiked aliquot

Ct = concentration of spike added.

Table C-11. INEEL Research Center MS/MSD data.

Analyte	Date	Well	Spike Added (µg /L)	Sample (µg/L)	MS (µg/L)	MS Recovery (%)	Criteria Met?	MSD (µg/L)	MSD Recovery (%)	Criteria Met?
PCE	03/16/04	TSF-05B	49.75	<10	53.2	106.9	Yes	48.1	96.7	Yes
PCE	03/18/04	TAN-25	49.75	ND	62.7	126.0	NA	No MSD	NA	NA
PCE	03/22/04	TAN-26	49.75	ND	49.8	100.1	Yes	56.9	114.4	Yes
PCE	03/23/04	TAN-29	49.75	<10	62.3	125.2	No	59.2	119.0	Yes
PCE	04/05/04	TSF-05B	49.75	ND	50.7	101.9	Yes	47.1	94.7	Yes
PCE	04/19/04	TAN-29	49.75	<10	59.0	118.6	Yes	58.8	118.2	Yes
PCE	04/20/04	TAN-26	49.75	ND	49.6	99.7	Yes	49.3	99.1	Yes
PCE	05/11/04	TAN-31	0.00	ND	0.0	NA	NA	0.0	NA	NA
PCE	05/13/04	TAN-25	0.00	ND	0.0	NA	NA	0.0	NA	NA
PCE	05/18/04	TAN-26	49.75	ND	46.9	94.3	Yes	52.2	104.9	Yes
PCE	06/15/04	TAN-1861	49.75	<10	48.7	97.9	Yes	45.8	92.1	Yes
PCE	07/19/04	TAN-29	49.75	13.2	67.8	109.7	Yes	71.8	117.8	Yes
PCE	07/20/04	TAN-26	49.75	Trace	46.7	93.9	Yes	51.2	102.9	Yes
PCE	08/17/04	TAN-31	49.75	ND	37.5	75.4	Yes	43.3	87.0	Yes
PCE	08/19/04	TAN-25	49.75	ND	0.0	0.0	No	45.8	92.1	Yes
PCE	08/23/04	TAN-26	49.75	ND	47.4	95.3	Yes	57.7	116.0	Yes
PCE	08/24/04	TAN-29	49.75	2.7	49.6	94.3	Yes	58.2	111.6	Yes
PCE	09/20/04	TAN-29	49.75	9.8	64.7	110.4	Yes	55.9	92.7	Yes
PCE	09/21/04	TAN-26	49.75	ND	51.2	102.9	Yes	50.4	101.3	Yes
PCE	10/12/04	TSF-05B	49.75	<10	36.8	74.0	Yes	37.6	75.6	Yes
PCE	10/14/04	TAN-25	49.75	<10	37.0	74.4	Yes	37.2	74.8	Yes
PCE	10/18/04	TAN-29	49.75	<10	51.7	103.9	Yes	56.8	114.2	Yes
PCE	10/19/04	TAN-26	49.75	ND	46.8	94.1	Yes	48.4	97.3	Yes
PCE	10/25/04	TSF-05A	40.0	ND	36.9	92.3	Yes	42.1	105.3	Yes
PCE	11/01/04	TSF-05B	40.0	ND	37.6	94.0	Yes	36.7	91.8	Yes
PCE	11/16/04	TAN-26	49.75	ND	50.0	100.5	Yes	51.1	102.7	Yes
PCE	11/16/04	TAN-1861	49.75	<10	37.1	74.6	Yes	38.6	77.6	Yes
PCE	12/14/04	TAN-D2	49.75	<10	43.6	87.6	Yes	45.6	91.7	Yes

Table C-11. (continued).

Analyte	Date	Well	Spike Added (µg /L)	Sample (µg/L)	MS (µg/L)	MS Recovery (%)	Criteria Met?	MSD (µg/L)	MSD Recovery (%)	Criteria Met?
PCE	12/14/04	TAN-1861	49.75	<10	44.9	90.3	Yes	46.0	92.5	Yes
PCE	01/11/05	TAN-31	49.75	ND	41.3	86.6	Yes	48.6	97.7	Yes
PCE	01/17/05	TAN-30A	49.75	<10	60.0	120.3	No	59.1	118.8	Yes
PCE	01/18/05	TAN-1859	49.75	<10	50.9	102.3	Yes	51.1	102.7	Yes
PCE	01/31/05	TSF-05A	40.0	ND	40.4	101.0	Yes	43.0	107.5	Yes
PCE	02/14/05	TAN-1859	49.75	ND	45.3	91.1	Yes	43.7	87.8	Yes
PCE	02/15/05	TAN-37A	49.75	1.8	51.4	99.7	Yes	51.4	99.7	Yes
PCE	02/28/05	TAN-31	49.75	ND	39.5	79.4	Yes	38.8	78.0	Yes
PCE	03/14/05	TAN-37A	49.75	<10	48.8	98.1	Yes	48.2	96.9	Yes
PCE	03/15/05	TAN-1859	49.75	ND	48.0	96.5	Yes	47.4	95.3	Yes
PCE	04/11/05	TAN-37A	49.75	2.3	49.9	95.7	Yes	51.6	99.1	Yes
PCE	04/12/05	TAN-1859	49.75	ND	50.1	100.7	Yes	51.4	103.3	Yes
PCE	05/09/05	TAN-37A	49.75	<10	46.8	94.1	Yes	46.9	94.3	Yes
PCE	05/10/05	TAN-1859	49.75	ND	43.1	86.5	Yes	47.6	95.6	Yes
PCE	06/14/05	TAN-28	49.75	3.4	43.4	80.5	Yes	42.8	79.2	Yes
PCE	06/15/05	TAN-29	49.75	13.4	58.3	90.1	Yes	57.2	87.9	Yes
TCE	03/16/04	TSF-05B	49.75	207.8	258.6	102.1	Yes	259.4	103.7	Yes
TCE	03/18/04	TAN-25	49.75	<10	66.7	134.1	No	No MSD	NA	NA
TCE	03/22/04	TAN-26	49.75	ND	53.7	107.9	Yes	55.8	112.2	Yes
TCE	03/23/04	TAN-29	49.75	907.7	897.7	-20.1	No	910.2	5.0	No
TCE	04/05/04	TSF-05B	49.75	<10	58.9	118.4	Yes	53.7	107.9	Yes
TCE	04/19/04	TAN-29	49.75	852.6	901.2	97.7	Yes	965.0	225.9	No
TCE	04/20/04	TAN-26	49.75	ND	51.0	102.5	Yes	52.3	105.1	Yes
TCE	05/11/04	TAN-31	49.75	<10	52.0	104.5	Yes	52.4	105.3	Yes
TCE	05/13/04	TAN-25	49.75	<10	30.1	60.5	No	59.6	119.8	Yes
TCE	05/18/04	TAN-26	49.75	ND	46.8	94.1	Yes	50.8	102.1	Yes
TCE	06/15/04	TAN-1861	49.75	61.4	104.3	86.2	Yes	96.7	71.0	Yes
TCE	07/19/04	TAN-29	49.75	720.9	695.4	-51.3	No	776.1	111.0	Yes
TCE	07/20/04	TAN-26	49.75	Trace	51.0	102.5	Yes	55.9	112.4	Yes
TCE	08/17/04	TAN-31	49.75	<10	50.0	100.5	Yes	64.1	128.8	No
TCE	08/19/04	TAN-25	49.75	108.8	0.0	-218.7	No	153.5	89.8	Yes

Table C-11. (continued).

Analyte	Date	Well	Spike Added (µg /L)	Sample (µg/L)	MS (µg/L)	MS Recovery (%)	Criteria Met?	MSD (µg/L)	MSD Recovery (%)	Criteria Met?
TCE	08/23/04	TAN-26	49.75	<10	53.4	107.3	Yes	58.0	116.6	Yes
TCE	08/24/04	TAN-29	49.75	553.8	592.8	78.4	Yes	589.6	72.0	Yes
TCE	09/20/04	TAN-29	TCE concentration was too high to perform MS/MSD							
TCE	09/21/04	TAN-26	49.75	<10	55.9	112.4	Yes	53.0	106.5	Yes
TCE	10/12/04	TSF-05B	49.75	109.5	147.1	75.6	Yes	147.0	75.4	Yes
TCE	10/14/04	TAN-25	49.75	212.3	220.6	16.7	No	223.1	21.7	No
TCE	10/18/04	TAN-29	49.75	647.1	625.0	-44.4	No	682.1	70.4	No
TCE	10/19/04	TAN-26	49.75	<10	49.9	100.3	Yes	49.2	98.9	Yes
TCE	10/25/04	TSF-05A	40.0	<10	42.7	106.8	Yes	41.7	104.3	Yes
TCE	11/01/04	TSF-05B	40.0	<10	39.1	97.8	Yes	38.7	96.8	Yes
TCE	11/16/04	TAN-26	49.75	<10	54.3	109.1	Yes	54.5	109.5	Yes
TCE	11/16/04	TAN-1861	49.75	39.0	93.5	109.5	Yes	93.2	108.9	Yes
TCE	12/14/04	TAN-D2	49.75	<10	49.6	99.7	Yes	50.3	101.1	Yes
TCE	12/14/04	TAN-1861	49.75	48.3	93.3	90.5	Yes	96.9	97.7	Yes
TCE	01/11/05	TAN-31	49.75	<10	50.2	100.9	Yes	48.3	97.1	Yes
TCE	01/17/05	TAN-30A	49.75	44.9	119.2	149.3	No	111.0	132.9	No
TCE	01/18/05	TAN-1859	49.75	<10	60.5	121.6	No	62.0	124.6	No
TCE	01/31/05	TSF-05A	40.0	<10	42.8	107.0	Yes	43.2	108.0	Yes
TCE	02/14/05	TAN-1859	49.75	2.7	57.9	111.0	Yes	57.9	111.0	Yes
TCE	02/15/05	TAN-37A	49.75	51.2	105.8	109.7	Yes	103.6	105.3	Yes
TCE	02/28/05	TAN-31	49.75	<10	49.5	99.5	Yes	49.0	98.5	Yes
TCE	03/14/05	TAN-37A	49.75	72.4	128.0	111.8	Yes	128.6	113.0	Yes
TCE	03/15/05	TAN-1859	49.75	2.5	62.8	121.2	No	62.0	119.6	Yes
TCE	04/11/05	TAN-37A	49.75	87.5	133.5	92.5	Yes	132.2	89.8	Yes
TCE	04/12/05	TAN-1859	49.75	3.0	53.2	100.9	Yes	56.0	106.5	Yes
TCE	05/09/05	TAN-37A	49.75	112.5	165.2	105.9	Yes	164.7	104.7	Yes
TCE	05/10/05	TAN-1859	49.75	<10	53.4	107.3	Yes	56.2	112.9	Yes
TCE	06/14/05	TAN-28	49.75	1213.8	TCE concentration too high to perform MS/MSD.					
TCE	06/15/05	TAN-29	49.75	537.4	TCE concentration too high to perform MS/MSD.					
cis-DCE	03/16/04	TSF-05B	49.75	227.6	263.9	73.0	Yes	260.4	65.9	No
cis-DCE	03/18/04	TAN-25	49.75	<10	46.2	92.9	Yes	No MSD	NA	NA

Table C-11. (continued).

Analyte	Date	Well	Spike Added (µg /L)	Sample (µg/L)	MS (µg/L)	MS Recovery (%)	Criteria Met?	MSD (µg/L)	MSD Recovery (%)	Criteria Met?
cis-DCE	03/22/04	TAN-26	49.75	<10	53.4	107.3	Yes	56.8	114.2	Yes
cis-DCE	03/23/04	TAN-29	49.75	140.7	51.2	-179.9	No	172.6	64.1	No
cis-DCE	04/05/04	TSF-05B	49.75	153.0	206.2	106.9	Yes	190.5	75.4	Yes
cis-DCE	04/19/04	TAN-29	49.75	120.9	145.4	49.2	No	164.2	87.0	Yes
cis-DCE	04/20/04	TAN-26	49.75	<10	48.9	98.3	Yes	51.3	103.1	Yes
cis-DCE	05/11/04	TAN-31	0.00	<10	0.0	NA	NA	0.0	NA	NA
cis-DCE	05/13/04	TAN-25	0.00	70.4	68.4	NA	NA	66.1	NA	NA
cis-DCE	05/18/04	TAN-26	49.75	<10	47.0	94.5	Yes	46.5	93.5	Yes
cis-DCE	06/15/04	TAN-1861	49.75	<10	52.0	104.5	Yes	49.1	98.7	Yes
cis-DCE	07/19/04	TAN-29	49.75	77.7	116.0	77.0	Yes	112.9	70.8	No
cis-DCE	07/20/04	TAN-26	49.75	Trace	53.1	106.7	Yes	56.3	113.2	Yes
cis-DCE	08/17/04	TAN-31	49.75	<10	54.9	110.4	Yes	59.6	119.8	Yes
cis-DCE	08/19/04	TAN-25	49.75	64.7	0.0	-130.1	No	98.6	68.1	No
cis-DCE	08/23/04	TAN-26	49.75	<10	53.2	106.9	Yes	57.4	115.4	Yes
cis-DCE	08/24/04	TAN-29	49.75	141.3	157.1	31.8	No	167.0	51.7	No
cis-DCE	09/20/04	TAN-29	49.75	122.7	165.5	86.0	Yes	146.6	48.0	No
cis-DCE	09/21/04	TAN-26	49.75	<10	56.4	113.4	Yes	50.0	100.5	Yes
cis-DCE	10/12/04	TSF-05B	49.75	185.2	209.3	48.4	No	207.3	44.4	No
cis-DCE	10/14/04	TAN-25	49.75	83.9	105.4	43.2	No	106.8	46.0	No
cis-DCE	10/18/04	TAN-29	49.75	110.7	136.5	51.9	No	148.4	75.8	Yes
cis-DCE	10/19/04	TAN-26	49.75	<10	48.8	98.1	Yes	48.9	98.3	Yes
cis-DCE	10/25/04	TSF-05A	40.0	cis-DCE concentration was too high to perform MS/MSD						
cis-DCE	11/01/04	TSF-05B	40.0	189.7	195.3	14.0	No	197.9	20.5	No
cis-DCE	11/16/04	TAN-26	49.75	<10	48.7	97.9	Yes	48.1	96.7	Yes
cis-DCE	11/16/04	TAN-1861	49.75	<10	46.2	92.9	Yes	45.0	90.5	Yes
cis-DCE	12/14/04	TAN-D2	49.75	ND	52.1	104.7	Yes	47.5	95.5	Yes
cis-DCE	12/14/04	TAN-1861	49.75	<10	50.5	101.5	Yes	55.4	111.4	Yes
cis-DCE	01/11/05	TAN-31	49.75	<10	47.3	95.1	Yes	45.5	91.5	Yes
cis-DCE	01/17/05	TAN-30A	49.75	<10	88.4	177.7	No	78.5	157.7	No
cis-DCE	01/18/05	TAN-1859	49.75	85.9	131.0	90.7	Yes	132.5	93.7	Yes
cis-DCE	01/31/05	TSF-05A	40.0	204.0	226.2	55.5	No	232.0	70.0	No
cis-DCE	02/14/05	TAN-1859	49.75	5.6	58.2	105.7	Yes	58.6	106.5	Yes

Table C-11. (continued).

Analyte	Date	Well	Spike Added (µg /L)	Sample (µg/L)	MS (µg/L)	MS Recovery (%)	Criteria Met?	MSD (µg/L)	MSD Recovery (%)	Criteria Met?
cis-DCE	02/15/05	TAN-37A	49.75	21.1	74.1	106.5	Yes	72.3	102.9	Yes
cis-DCE	02/28/05	TAN-31	49.75	<10	52.9	106.3	Yes	52.3	105.1	Yes
cis-DCE	03/14/05	TAN-37A	49.75	17.7	69.6	104.3	Yes	68.7	102.5	Yes
cis-DCE	03/15/05	TAN-1859	49.75	4.1	58.6	109.5	Yes	58.1	108.5	Yes
cis-DCE	04/11/05	TAN-37A	49.75	19.4	68.1	97.9	Yes	66.3	94.3	Yes
cis-DCE	04/12/05	TAN-1859	49.75	5.7	55.7	100.5	Yes	55.7	100.5	Yes
cis-DCE	05/09/05	TAN-37A	49.75	21.7	75.0	107.0	Yes	74.3	105.6	Yes
cis-DCE	05/10/05	TAN-1859	49.75	5.5	60.2	110.0	Yes	61.3	112.1	Yes
cis-DCE	06/14/05	TAN-28	49.75	122.4	147.2	49.9	No	144.3	43.9	No
cis-DCE	06/15/05	TAN-29	49.75	48.8	91.8	86.5	Yes	92.1	87.0	Yes
trans-DCE	03/16/04	TSF-05B	49.75	323.8	363.1	79.0	Yes	361.9	76.6	Yes
trans-DCE	03/18/04	TAN-25	49.75	226.9	270.4	87.4	Yes	No MSD	NA	NA
trans-DCE	03/22/04	TAN-26	49.75	82.7	151.7	138.7	No	146.3	127.8	No
trans-DCE	03/23/04	TAN-29	49.75	129.8	172.4	85.6	Yes	185.9	112.8	Yes
trans-DCE	04/05/04	TSF-05B	49.75	221.6	273.6	104.5	Yes	257.0	71.2	Yes
trans-DCE	04/19/04	TAN-29	49.75	81.4	115.7	68.9	No	123.2	84.0	Yes
trans-DCE	04/20/04	TAN-26	49.75	53.6	48.9	97.9	Yes	51.3	105.3	Yes
trans-DCE	05/11/04	TAN-31	49.75	188.8	215.8	54.3	No	220.0	62.7	No
trans-DCE	05/13/04	TAN-25	0.00	131.7	162.2	NA	NA	183.9	NA	NA
trans-DCE	05/18/04	TAN-26	49.75	49.8	47.0	87.8	Yes	46.5	95.1	Yes
trans-DCE	06/15/04	TAN-1861	49.75	28.5	72.9	89.2	Yes	66.6	76.6	Yes
trans-DCE	07/19/04	TAN-29	49.75	10.4	63.7	107.1	Yes	63.3	106.3	Yes
trans-DCE	07/20/04	TAN-26	49.75	55.9	102.7	94.1	Yes	110.1	108.9	Yes
trans-DCE	08/17/04	TAN-31	49.75	177.6	217.7	80.6	Yes	226.3	97.9	Yes
trans-DCE	08/19/04	TAN-25	49.75	110.5	No MS	NA	NA	146.5	72.4	Yes
trans-DCE	08/23/04	TAN-26	49.75	57.4	113.9	113.6	Yes	120.7	127.2	No
trans-DCE	08/24/04	TAN-29	49.75	100.2	139.4	78.8	Yes	148.1	96.3	Yes
trans-DCE	09/20/04	TAN-29	49.75	79.6	133.2	107.7	Yes	120.1	81.4	Yes
trans-DCE	09/21/04	TAN-26	49.75	63.3	128.5	131.1	No	118.0	109.9	Yes
trans-DCE	10/12/04	TSF-05B	49.75	130.9	165.0	68.5	No	165.1	68.7	No
trans-DCE	10/14/04	TAN-25	49.75	117.0	143.2	52.7	No	143.4	53.1	No

Table C-11. (continued).

Analyte	Date	Well	Spike Added (µg /L)	Sample (µg/L)	MS (µg/L)	MS Recovery (%)	Criteria Met?	MSD (µg/L)	MSD Recovery (%)	Criteria Met?
trans-DCE	10/18/04	TAN-29	49.75	88.4	126.1	75.8	Yes	136.5	96.7	Yes
trans-DCE	10/19/04	TAN-26	49.75	70.9	113.1	84.8	Yes	116.3	91.3	Yes
trans-DCE	10/25/04	TSF-05A	40.0	267.4	292.7	63.3	No	288.7	53.3	No
trans-DCE	11/01/04	TSF-05B	40.0	226.9	254.1	68.0	No	251.7	62.0	No
trans-DCE	11/16/04	TAN-26	49.75	81.8	125.2	87.2	Yes	126.2	89.2	Yes
trans-DCE	11/16/04	TAN-1861	49.75	17.1	63.9	94.1	Yes	64.9	96.1	Yes
trans-DCE	12/14/04	TAN-D2	49.75	<10	49.8	100.1	Yes	49.0	98.5	Yes
trans-DCE	12/14/04	TAN-1861	49.75	28.0	72.6	89.6	Yes	76.0	96.5	Yes
trans-DCE	01/11/05	TAN-31	49.75	113.7	158.7	90.5	Yes	154.1	81.2	Yes
trans-DCE	01/17/05	TAN-30A	49.75	108.4	153.9	91.5	Yes	144.5	72.6	Yes
trans-DCE	01/18/05	TAN-1859	49.75	180.9	206.8	52.1	No	208.5	55.5	No
trans-DCE	01/31/05	TSF-05A	40.0	215.5	243.1	69.0	No	245.9	76.0	Yes
trans-DCE	02/14/05	TAN-1859	49.75	187.8	232.9	90.7	Yes	237.7	100.3	Yes
trans-DCE	02/15/05	TAN-37A	49.75	275.1	310.2	70.6	No	305.8	61.7	No
trans-DCE	02/28/05	TAN-31	49.75	106.5	153.2	93.9	Yes	156.4	100.3	Yes
trans-DCE	03/14/05	TAN-37A	49.75	247.9	292.6	89.8	Yes	295.6	95.9	Yes
trans-DCE	03/15/05	TAN-1859	49.75	177.8	219.4	83.6	Yes	216.3	77.4	Yes
trans-DCE	04/11/05	TAN-37A	49.75	248.3	274.4	52.5	No	270.4	44.4	No
trans-DCE	04/12/05	TAN-1859	49.75	212.5	241.7	58.7	No	240.9	57.1	No
trans-DCE	05/09/05	TAN-37A	49.75	219.7	250.5	61.9	No	249.8	60.6	No
trans-DCE	05/10/05	TAN-1859	49.75	263.6	291.3	55.6	No	296.1	65.3	No
trans-DCE	06/14/05	TAN-28	49.75	101.3	137.4	72.6	Yes	136.6	71	Yes
trans-DCE	06/15/05	TAN-29	49.75	8.6	60.2	103.7	Yes	59.5	102.4	Yes
VC	03/16/04	TSF-05B	0.00	100.5	98.3	NA	NA	100.5	NA	NA
VC	03/18/04	TAN-25	49.75	12.5	70.2	116.0	Yes	No MSD	NA	NA
VC	03/22/04	TAN-26	49.75	<10	54.2	108.9	Yes	68.5	137.7	No
VC	03/23/04	TAN-29	49.75	<10	33.9	68.1	No	37.6	75.6	Yes
VC	04/05/04	TSF-05B	49.75	12.0	40.2	56.7	No	44.7	65.7	No
VC	04/19/04	TAN-29	49.75	<10	34.4	69.1	No	48.4	97.3	Yes
VC	04/20/04	TAN-26	49.75	<10	48.1	96.7	Yes	56.3	113.2	Yes
VC	05/11/04	TAN-31	49.75	<10	37.0	74.4	Yes	38.3	77.0	Yes

Table C-11. (continued).

Analyte	Date	Well	Spike Added (µg /L)	Sample (µg/L)	MS (µg/L)	MS Recovery (%)	Criteria Met?	MSD (µg/L)	MSD Recovery (%)	Criteria Met?
VC	05/13/04	TAN-25	0.00	ND	27.9	NA	NA	38.1	NA	NA
VC	05/18/04	TAN-26	49.75	ND	38.8	78.0	Yes	59.8	120.2	No
VC	06/15/04	TAN-1861	49.75	ND	51.8	104.1	Yes	34.4	69.1	No
VC	07/19/04	TAN-29	49.75	ND	39.6	79.6	Yes	47.0	94.5	Yes
VC	07/20/04	TAN-26	49.75	ND	50.0	100.5	Yes	54.5	109.5	Yes
VC	08/17/04	TAN-31	49.75	5.1	63.4	117.2	Yes	60.6	111.6	Yes
VC	08/19/04	TAN-25	49.75	<10	0.0	0.0	No	33.3	66.9	No
VC	08/23/04	TAN-26	49.75	6.8	79.3	145.7	No	60.2	107.3	Yes
VC	08/24/04	TAN-29	49.75	5.3	36.8	63.3	No	43.1	76.0	Yes
VC	09/20/04	TAN-29	49.75	3.1	40.3	74.8	Yes	38.8	71.8	Yes
VC	09/21/04	TAN-26	49.75	5.0	47.2	84.8	Yes	54.0	98.5	Yes
VC	10/12/04	TSF-05B	49.75	91.8	96.9	NR	No	94.3	NR	No
VC	10/14/04	TAN-25	49.75	18.0	36.7	37.6	No	37.4	39.0	No
VC	10/18/04	TAN-29	49.75	3.5	33.1	59.5	No	34.9	63.1	No
VC	10/19/04	TAN-26	49.75	ND	49.9	100.3	Yes	51.0	102.5	Yes
VC	10/25/04	TSF-05A	NR (40)	92.2	94.4	NR	No	90.4	NR	No
VC	11/01/04	TSF-05B	40.0	65.4	78.4	32.5	No	78.0	31.5	No
VC	11/16/04	TAN-26	49.75	28.1	55.2	54.5	No	40.9	25.7	No
VC	11/16/04	TAN-1861	49.75	1.0	41.5	81.4	Yes	37.8	74.0	Yes
VC	12/14/04	TAN-D2	49.75	ND	43.1	86.6	Yes	49.1	98.7	Yes
VC	12/14/04	TAN-1861	49.75	10.5	60.9	101.3	Yes	54.2	87.8	Yes
VC	01/11/05	TAN-31	49.75	<10	26.5	53.3	No	28.2	56.7	No
VC	01/17/05	TAN-30A	49.75	3.5	50.2	93.9	Yes	51.8	97.1	Yes
VC	01/18/05	TAN-1859	49.75	<10	45.1	90.7	Yes	45.8	92.1	Yes
VC	01/31/05	TSF-05A	40.0	64.5	77.2	31.8	No	76.8	30.8	No
VC	02/14/05	TAN-1859	49.75	7.3	44.2	74.2	Yes	44.0	73.8	Yes
VC	02/15/05	TAN-37A	49.75	17.8	45.7	56.1	No	46.2	57.1	No
VC	02/28/05	TAN-31	49.75	3.2	52.8	99.7	Yes	51.9	97.9	Yes
VC	03/14/05	TAN-37A	49.75	8.5	46.8	77.0	Yes	45.7	74.8	Yes
VC	03/15/05	TAN-1859	49.75	5.4	42.7	75.0	Yes	42.1	73.8	Yes
VC	04/11/05	TAN-37A	49.75	4.4	35.5	62.5	No	35.5	62.5	No
VC	04/12/05	TAN-1859	49.75	3.4	29.4	52.3	No	29.7	52.9	No

Table C-11. (continued).

Analyte	Date	Well	Spike Added (µg /L)	Sample (µg/L)	MS (µg/L)	MS Recovery (%)	Criteria Met?	MSD (µg/L)	MSD Recovery (%)	Criteria Met?
VC	05/09/05	TAN-37A	49.75	6.5	46.7	81.0	Yes	44.8	77.0	Yes
VC	05/10/05	TAN-1859	49.75	7.8	45.4	75.5	Yes	44.9	74.4	Yes
VC	06/13/05	TAN-28	49.75	10.6	38.9	56.9	No	38.1	55.4	No
VC	06/14/05	TAN-29	49.75	ND	44.7	89.9	Yes	44.4	89.2	Yes

NR = Not reported.

Table C-12. Summary of MS/MSD sample results.

Analyte	Number/Percentage of MS/MSD Samples that Met Target Percent Recoveries
PCE	79 of 82 samples 96%
TCE	54 of 81 samples 67%
cis-DCE	58 of 81 samples 72%
trans-DCE	56 of 84 samples 67%
VC	47 of 82 samples 57%

Table C-13. Off-site laboratory MS/MSD data.

Analyte	Date	Spike Added (µg/L)	Sample (µg/L)	MS (µg/L)	MS Recovery (%)	Criteria Met?	MSD (µg/L)	MSD Recovery (%)	Criteria Met?
TCE	05/17/04	50	34.1	78.6	89	Yes	77.8	87	Yes
TCE	05/18/04	50	0	48.2	96	Yes	49.4	99	Yes
TCE	11/16/04	50	51.8	95.6	88	Yes	95.7	88	Yes
TCE	11/16/04	50	0	54.0	108	Yes	54.3	109	Yes
TCE	06/14/05	50	1,430	1,590	332	No	1,480	108	Yes
TCE	06/15/05	50	480	513	65	No	509	57	No

C-1.2 Precision

Precision is an assessment of reproducibility of measurements under a given set of conditions. Overall precision was assessed through collection and analysis of duplicate samples at the ISB field laboratory, IRC, and off-site laboratories. Duplicate samples are defined as two samples collected for the same analyses during a single mobilization. If one or both of the duplicate samples are reported below the

method detection limit, then an RPD is not calculated. Target RPDs for duplicate samples analyzed in the ISB field laboratory are stated in TPR-166, "ISB Field Laboratory Procedure." RPDs are not specified for analyses conducted at the IRC or off-site laboratories, except for TCE, which has a target RPD of 14%. RPDs for ISB field laboratory duplicates are presented in Table C-14; IRC duplicates in Table C-15; off-site VOCs in Table C-16; and tritium and Sr-90 in Table C-17.

Table C-14. Relative percent differences for ISB field laboratory duplicates.

Analyte	Date	Well	Sample (mg/L)	Duplicate (mg/L)	RPD (%)	Target RPD (%)	Criteria Met?
COD	03/16/04	TAN-25	9,522	84	196.5	25	No
COD	03/18/04	TSF-05A	7,020	7,497	6.6	25	Yes
COD	03/22/04	TAN-31	1,761	1,812	2.9	25	Yes
COD	03/23/04	TAN-37A	6	0	NA	NA	NA
COD	03/24/04	TAN-27	5	21	123.1	50	No
COD	04/05/04	TAN-31	76	78	2.6	50	Yes
COD	04/19/04	TAN-37B	36	2	178.9	50	No
COD	04/20/04	TAN-25	90	73	20.9	50	Yes
COD	05/11/04	TAN-25	14,148	12,744	10.4	25	Yes
COD	05/13/04	TSF-05A	6,840	7,605	10.6	25	Yes
COD	05/17/04	TAN-37C	31	26	17.5	50	Yes
COD	05/18/04	TAN-31	1,749	1,851	5.7	25	Yes
COD	05/19/04	TAN-10A	10	2	133.3	50	No
COD	06/01/04	TSF-05B	2,259	2,397	5.9	25	Yes
COD	06/14/04	TAN-37C	40	30	28.6	50	Yes
COD	06/15/04	TSF-05B	256	245	4.4	25	Yes
COD	06/16/04	TAN-27	13	16	20.7	50	Yes
COD	07/19/04	TAN-37B	16	16	0.0	50	Yes
COD	07/20/04	TAN-31	25	28	11.3	50	Yes
COD	07/21/04	TAN-10A	19	25	27.3	50	Yes
COD	08/17/04	TSF-05B	21,096	19,116	9.8	25	Yes
COD	08/19/04	TSF-05A	6,147	6,435	4.6	25	Yes
COD	08/23/04	TAN-31	4,356	4,392	0.8	25	Yes
COD	08/24/04	TAN-28	33	9	114.3	50	No
COD	08/25/04	TAN-10A	25	0	NA	NA	NA
COD	09/07/04	TAN-25	1,776	1,689	5.0	25	Yes
COD	09/20/04	TAN-28	0	0	NA	NA	NA
COD	09/21/04	TAN-31	109	111	1.8	50	Yes
COD	10/12/04	TAN-25	18,900	17,676	6.7	25	Yes
COD	10/14/04	TSF-05A	7,875	7,587	3.7	25	Yes
COD	10/18/04	TAN-28	0	0	NA	NA	NA

Table C-14. (continued).

Analyte	Date	Well	Sample (mg/L)	Duplicate (mg/L)	RPD (%)	Target RPD (%)	Criteria Met?
COD	10/19/04	TAN-25	4,995	4,581	8.7	25	Yes
COD	10/25/04	TAN-31	1,509	1,557	3.1	25	Yes
COD	11/01/04	TAN-31	281	244	14.1	25	Yes
COD	11/15/04	TAN-37C	0	0	NA	NA	NA
COD	11/16/04	TAN-25	108	104	3.8	50	Yes
COD	11/17/04	TAN-10A	1	0	NA	NA	NA
COD	12/13/04	TAN-37B	6	23	117.2	50	No
COD	12/14/04	TAN-25	69	65	6.0	50	Yes
COD	01/11/05	TAN-25	19,332	19,584	1.3	25	Yes
COD	01/13/05	TSF-05A	10,404	9,540	8.7	25	Yes
COD	01/17/05	TAN-37B	18	23	24.4	50	Yes
COD	01/18/05	TAN-25	5,670	5,706	0.6	25	Yes
COD	01/24/05	TSF-05B	3,492	3,123	11.2	25	Yes
COD	01/31/05	TSF-05B	1,029	1,206	15.8	25	Yes
COD	02/14/05	TAN-29	42	24	54.5	50	No
COD	02/15/05	TAN-25	153	142	7.5	25	Yes
COD	03/14/05	TAN-10A	3	15	133.3	50	No
COD	03/15/05	TAN-25	293	49	142.7	50	No
COD	04/11/05	TAN-10A	25	34	30.5	50	Yes
COD	04/12/05	TAN-29	43	50	15.1	50	Yes
COD	05/09/05	TSF-05B	42	47	11.2	50	Yes
COD	05/10/05	TSF-05A	6	13	73.7	50	No
COD	06/14/05	TAN-27	0	0	NA	NA	NA
COD	06/15/05	TAN-1861	5	2	86	50	No
Iron	03/16/04	TAN-25	5.60	5.00	11.3	25	Yes
Iron	03/18/04	TSF-05A	6.20	6.00	3.3	25	Yes
Iron	03/22/04	TAN-31	5.80	5.60	3.5	25	Yes
Iron	03/23/04	TAN-37A	0.58	0.59	1.7	25	Yes
Iron	03/24/04	TAN-27	0.03	0.03	0.0	50	Yes
Iron	04/05/04	TAN-31	4.20	4.50	6.9	25	Yes
Iron	04/19/04	TAN-37B	1.10	1.10	0.0	25	Yes
Iron	04/20/04	TAN-25	2.06	1.76	15.7	25	Yes
Iron	05/11/04	TAN-25	4.70	4.40	6.6	25	Yes
Iron	05/13/04	TSF-05A	5.20	5.00	3.9	25	Yes
Iron	05/17/04	TAN-37C	4.20	4.20	0.0	25	Yes
Iron	05/18/04	TAN-31	5.00	4.80	4.1	25	Yes

Table C-14. (continued).

Analyte	Date	Well	Sample (mg/L)	Duplicate (mg/L)	RPD (%)	Target RPD (%)	Criteria Met?
Iron	05/19/04	TAN-10A	1.19	1.20	0.8	25	Yes
Iron	06/01/04	TSF-05B	4.40	4.40	0.0	25	Yes
Iron	06/14/04	TAN-37C	3.40	3.40	0.0	25	Yes
Iron	06/15/04	TSF-05B	4.50	4.30	4.5	25	Yes
Iron	06/16/04	TAN-27	0.03	0.04	28.6	50	Yes
Iron	07/19/04	TAN-37B	0.52	0.48	8.0	25	Yes
Iron	07/20/04	TAN-31	3.40	3.40	0.0	25	Yes
Iron	07/21/04	TAN-10A	1.21	1.22	0.8	25	Yes
Iron	08/17/04	TSF-05B	2.95	3.40	14.2	25	Yes
Iron	08/19/04	TSF-05A	4.00	3.90	2.5	25	Yes
Iron	08/23/04	TAN-31	4.30	4.40	2.3	25	Yes
Iron	08/24/04	TAN-28	0.02	0.03	40.0	50	Yes
Iron	08/25/04	TAN-10A	1.05	1.20	13.3	25	Yes
Iron	09/07/04	TAN-25	4.50	4.40	2.2	25	Yes
Iron	09/20/04	TAN-28	0.02	0.02	0.0	50	Yes
Iron	09/21/04	TAN-31	4.80	4.90	2.1	25	Yes
Iron	10/12/04	TAN-25	2.34	4.00	52.4	25	No
Iron	10/14/04	TSF-05A	3.70	4.00	7.8	25	Yes
Iron	10/18/04	TAN-28	0.00	0.02	NA	NA	NA
Iron	10/19/04	TAN-25	4.00	3.90	2.5	25	Yes
Iron	10/25/04	TAN-31	4.40	4.60	4.4	25	Yes
Iron	11/01/04	TAN-31	6.80	6.80	0.0	25	Yes
Iron	11/15/04	TAN-37C	3.20	2.96	7.8	25	Yes
Iron	11/16/04	TAN-25	4.70	4.80	2.1	25	Yes
Iron	11/17/04	TAN-10A	0.96	0.88	8.7	25	Yes
Iron	12/13/04	TAN-37B	0.56	0.56	0.0	25	Yes
Iron	12/14/04	TAN-25	4.90	4.80	2.1	25	Yes
Iron	01/11/05	TAN-25	4.00	4.00	0.0	25	Yes
Iron	01/13/05	TSF-05A	4.50	4.50	0.0	25	Yes
Iron	01/17/05	TAN-37B	0.66	0.64	3.1	25	Yes
Iron	01/18/05	TAN-25	4.20	4.20	0.0	25	Yes
Iron	01/24/05	TSF-05B	5.20	5.20	0.0	25	Yes
Iron	01/31/05	TSF-05B	4.00	4.20	4.9	25	Yes
Iron	02/14/05	TAN-29	0.03	0.02	40.0	50	Yes
Iron	02/15/05	TAN-25	5.20	5.10	1.9	25	Yes
Iron	02/28/05	TSF-05B	4.20	4.20	0.0	25	Yes

Table C-14. (continued).

Analyte	Date	Well	Sample (mg/L)	Duplicate (mg/L)	RPD (%)	Target RPD (%)	Criteria Met?
Iron	03/14/05	TAN-10A	1.17	1.14	2.6	25	Yes
Iron	03/15/05	TAN-25	4.40	4.40	0.0	25	Yes
Iron	03/29/05	TSF-05A	3.50	3.30	5.9	25	Yes
Iron	04/11/05	TAN-10A	1.12	1.08	3.6	25	Yes
Iron	04/12/05	TAN-29	0.03	0.04	28.6	50	Yes
Iron	04/25/05	TSF-05B	4.40	4.20	4.7	25	Yes
Iron	05/09/05	TSF-05B	7.00	7.50	6.9	25	Yes
Iron	05/10/05	TSF-05A	3.70	3.80	2.7	25	Yes
Iron	05/24/05	TAN-31	5.00	5.50	9.5	25	Yes
Iron	06/14/05	TAN-27	0.46	0.43	6.7	25	Yes
Iron	06/15/05	TAN-1861	0.14	0.18	25	50	Yes
Sulfate	03/16/04	TAN-25	0	0	NA	NA	NA
Sulfate	03/18/04	TSF-05A	0	0	NA	NA	NA
Sulfate	03/22/04	TAN-31	0	0	NA	NA	NA
Sulfate	03/23/04	TAN-37A	39	35	10.8	25	Yes
Sulfate	03/24/04	TAN-27	36	36	0.0	25	Yes
Sulfate	04/05/04	TAN-31	0	0	NA	NA	NA
Sulfate	04/19/04	TAN-37B	39	36	8.0	25	Yes
Sulfate	04/20/04	TAN-25	0	0	NA	NA	NA
Sulfate	05/11/04	TAN-25	0	0	NA	NA	NA
Sulfate	05/13/04	TSF-05A	0	0	NA	NA	NA
Sulfate	05/17/04	TAN-37C	0	0	NA	NA	NA
Sulfate	05/18/04	TAN-31	0	0	NA	NA	NA
Sulfate	05/19/04	TAN-10A	47	46	2.2	25	Yes
Sulfate	06/01/04	TSF-05B	0	0	NA	NA	NA
Sulfate	06/14/04	TAN-37C	0	0	NA	NA	NA
Sulfate	06/15/04	TSF-05B	0	0	NA	NA	NA
Sulfate	06/16/04	TAN-27	37	41	10.3	25	Yes
Sulfate	07/19/04	TAN-37B	36	36	0.0	25	Yes
Sulfate	07/20/04	TAN-31	0	0	NA	NA	NA
Sulfate	07/21/04	TAN-10A	42	41	2.4	25	Yes
Sulfate	08/17/04	TSF-05B	11	7	44.4	25	No
Sulfate	08/19/04	TSF-05A	14	14	0.0	25	Yes
Sulfate	08/23/04	TAN-31	7	5	33.3	25	No
Sulfate	08/24/04	TAN-28	37	36	2.7	25	Yes
Sulfate	08/25/04	TAN-10A	35	35	0.0	25	Yes

Table C-14. (continued).

Analyte	Date	Well	Sample (mg/L)	Duplicate (mg/L)	RPD (%)	Target RPD (%)	Criteria Met?
Sulfate	09/07/04	TAN-25	0	0	NA	NA	NA
Sulfate	09/20/04	TAN-28	39	40	2.5	25	Yes
Sulfate	09/21/04	TAN-31	0	0	NA	NA	NA
Sulfate	10/12/04	TAN-25	7	12	52.6	25	No
Sulfate	10/14/04	TSF-05A	12	11	8.7	25	Yes
Sulfate	10/18/04	TAN-28	45	42	6.9	25	Yes
Sulfate	10/19/04	TAN-25	0	0	NA	NA	NA
Sulfate	10/25/04	TAN-31	0	0	NA	NA	NA
Sulfate	11/01/04	TAN-31	0	0	NA	NA	NA
Sulfate	11/15/04	TAN-37C	0	0	NA	NA	NA
Sulfate	11/16/04	TAN-25	0	0	NA	NA	NA
Sulfate	11/17/04	TAN-10A	45	47	4.4	25	Yes
Sulfate	12/13/04	TAN-37B	41	40	2.5	25	Yes
Sulfate	12/14/04	TAN-25	0	0	NA	NA	NA
Sulfate	01/11/05	TAN-25	12	11	8.7	25	Yes
Sulfate	01/13/05	TSF-05A	1	1	0.0	25	Yes
Sulfate	01/17/05	TAN-37B	41	40	2.5	25	Yes
Sulfate	01/18/05	TAN-25	0	0	NA	NA	NA
Sulfate	01/24/05	TSF-05B	0	0	NA	NA	NA
Sulfate	01/31/05	TSF-05B	0	0	NA	NA	NA
Sulfate	02/14/05	TAN-29	43	42	2.4	25	Yes
Sulfate	02/15/05	TAN-25	0	0	NA	NA	NA
Sulfate	02/28/05	TSF-05B	0	0	NA	NA	NA
Sulfate	03/14/05	TAN-10A	48	48	0.0	25	Yes
Sulfate	03/15/05	TAN-25	0	0	NA	NA	NA
Sulfate	03/29/05	TSF-05A	0	0	NA	NA	NA
Sulfate	04/11/05	TAN-10A	46	47	2.2	25	Yes
Sulfate	04/12/05	TAN-29	47	47	0.0	25	Yes
Sulfate	04/25/05	TSF-05B	0	0	NA	NA	NA
Sulfate	05/09/05	TSF-05B	0	0	NA	NA	NA
Sulfate	05/10/05	TSF-05A	11	3	114.3	25	No
Sulfate	05/24/05	TAN-31	0	0	NA	NA	NA
Sulfate	06/14/05	TAN-27	45	46	2.2	25	Yes
Sulfate	06/15/05	TAN-1861	46	47	2.2	25	Yes
Alkalinity	03/22/04	TAN-31	2,520	2,540	0.8	25	Yes
Alkalinity	03/23/04	TAN-37A	380	375	1.3	25	Yes

Table C-14. (continued).

Analyte	Date	Well	Sample (mg/L)	Duplicate (mg/L)	RPD (%)	Target RPD (%)	Criteria Met?
Alkalinity	03/24/04	TAN-27	243	242	0.4	25	Yes
Alkalinity	04/19/04	TAN-37B	436	444	1.8	25	Yes
Alkalinity	04/20/04	TAN-25	4,880	4,200	15.0	25	Yes
Alkalinity	05/17/04	TAN-37C	2,640	2,670	1.1	25	Yes
Alkalinity	05/18/04	TAN-31	2,320	2,380	2.6	25	Yes
Alkalinity	05/19/04	TAN-10A	236	237	0.4	25	Yes
Alkalinity	06/14/04	TAN-37C	2,070	2,100	1.4	25	Yes
Alkalinity	06/15/04	TSF-05B	3,240	4,020	21.5	25	Yes
Alkalinity	06/16/04	TAN-27	237	235	0.8	25	Yes
Alkalinity	07/19/04	TAN-37B	432	430	0.5	25	Yes
Alkalinity	07/20/04	TAN-31	1,200	1,310	8.8	25	Yes
Alkalinity	07/21/04	TAN-10A	253	239	5.7	25	Yes
Alkalinity	08/23/04	TAN-31	2,110	2,030	3.9	25	Yes
Alkalinity	08/24/04	TAN-28	316	312	1.3	25	Yes
Alkalinity	08/25/04	TAN-10A	242	244	0.8	25	Yes
Alkalinity	09/20/04	TAN-28	324	328	1.2	25	Yes
Alkalinity	09/21/04	TAN-31	2,970	3,020	1.7	25	Yes
Alkalinity	10/18/04	TAN-28	330	328	0.6	25	Yes
Alkalinity	10/19/04	TAN-25	3,600	3,920	8.5	25	Yes
Alkalinity	11/15/04	TAN-37C	4,360	4,420	1.4	25	Yes
Alkalinity	11/16/04	TAN-25	2,520	2,560	1.6	25	Yes
Alkalinity	11/17/04	TAN-10A	252	256	1.6	25	Yes
Alkalinity	12/13/04	TAN-37B	602	604	0.3	25	Yes
Alkalinity	12/14/04	TAN-25	5,920	5,720	3.4	25	Yes
Alkalinity	01/17/05	TAN-37B	522	522	0.0	25	Yes
Alkalinity	01/18/05	TAN-25	4,960	4,920	0.8	25	Yes
Alkalinity	02/14/05	TAN-29	218	223	2.3	25	Yes
Alkalinity	02/15/05	TAN-25	6,460	6,020	7.1	25	Yes
Alkalinity	03/14/05	TAN-10A	264	259	1.9	25	Yes
Alkalinity	03/15/05	TAN-25	4,800	4,960	3.3	25	Yes
Alkalinity	04/11/05	TAN-10A	264	267	1.1	25	Yes
Alkalinity	04/12/05	TAN-29	244	252	3.2	25	Yes
Alkalinity	05/09/05	TSF-05B	2,560	2,630	2.7	25	Yes
Alkalinity	05/10/05	TSF-05A	2,260	2,240	0.9	25	Yes
Alkalinity	06/14/05	TAN-27	248	248	0	25	Yes
Alkalinity	06/15/05	TAN-1861	386	378	2.1	25	Yes

Table C-14. (continued).

Analyte	Date	Well	Sample (mg/L)	Duplicate (mg/L)	RPD (%)	Target RPD (%)	Criteria Met?
Ammonia	05/17/04	TAN-37C	0.21	0.19	10.0	50	Yes
Ammonia	05/18/04	TAN-31	0.03	0.00	NA	NA	NA
Ammonia	05/19/04	TAN-10A	0.07	0.03	80.0	50	No
Ammonia	11/15/04	TAN-37C	0.51	0.49	4.0	50	Yes
Ammonia	11/16/04	TAN-25	2.75	2.75	0.0	50	Yes
Ammonia	11/17/05	TAN-10A	0.00	0.00	NA	NA	NA
Ammonia	06/14/05	TAN-27	0.11	0.13	16.7	50	Yes
Ammonia	06/15/05	TAN-1861	0.24	0.19	23.3	50	Yes
Phosphate	05/17/04	TAN-37C	1.58	1.53	3.2	25	Yes
Phosphate	05/18/04	TAN-31	1.13	1.01	11.2	25	Yes
Phosphate	05/19/04	TAN-10A	0.60	0.60	0.0	25	Yes
Phosphate	11/15/04	TAN-37C	0.59	0.52	12.6	25	Yes
Phosphate	11/16/04	TAN-25	0.09	0.00	NA	NA	NA
Phosphate	11/17/05	TAN-10A	0.19	1.07	139.7	25	No
Phosphate	06/14/05	TAN-27	0.51	0.36	34.5	25	No
Phosphate	06/15/05	TAN-1861	0.43	0.39	9.8	25	Yes

Table C-15. Relative percent differences for IRC duplicates.

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
PCE	03/16/04	TAN-25	ND	ND	NA
PCE	03/18/04	TSF-05A	ND	ND	NA
PCE	03/22/04	TAN-31	5.0	5.0	NA
PCE	03/23/04	TAN-37A	5.0	5.0	NA
PCE	03/24/04	TAN-27	5.0	5.0	NA
PCE	04/05/04	TAN-31	ND	ND	NA
PCE	04/19/04	TAN-37B	5.0	5.0	NA
PCE	04/20/04	TAN-25	ND	ND	NA
PCE	05/11/04	TAN-25	ND	ND	NA
PCE	05/13/04	TSF-05A	5.0	5.0	NA
PCE	05/17/04	TAN-37C	ND	ND	NA
PCE	05/18/04	TAN-31	5.0	5.0	NA
PCE	05/19/04	TAN-10A	5.0	5.0	NA
PCE	06/01/04	TSF-05B	ND	ND	NA

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
PCE	06/14/04	TAN-37C	ND	ND	NA
PCE	06/15/04	TSF-05B	ND	ND	NA
PCE	06/16/04	TAN-27	5.0	5.0	NA
PCE	07/19/04	TAN-37B	trace	trace	NA
PCE	07/20/04	TAN-31	ND	ND	NA
PCE	07/21/04	TAN-10A	1.9	trace	NA
PCE	08/17/04	TSF-05B	5.0	5.0	NA
PCE	08/19/04	TSF-05A	ND	ND	NA
PCE	08/23/04	TAN-31	5.0	5.0	NA
PCE	08/24/04	TAN-28	5.4	5.7	5.4
PCE	08/25/04	TAN-10A	5.0	5.0	NA
PCE	09/07/04	TAN-25	ND	ND	NA
PCE	09/20/04	TAN-28	7.7	7.6	1.3
PCE	09/21/04	TAN-31	ND	ND	NA
PCE	10/12/04	TAN-25	5.0	5.0	NA
PCE	10/14/04	TSF-05A	ND	ND	NA
PCE	10/18/04	TAN-28	ND	ND	NA
PCE	10/19/04	TAN-25	ND	ND	NA
PCE	10/25/04	TAN-31	ND	ND	NA
PCE	11/01/04	TAN-31	ND	ND	NA
PCE	11/15/04	TAN-37C	ND	ND	NA
PCE	11/16/04	TAN-25	ND	ND	NA
PCE	11/17/04	TAN-10A	5.0	5.0	NA
PCE	12/13/04	TAN-37B	ND	ND	NA
PCE	12/14/04	TAN-25	ND	ND	NA
PCE	01/11/05	TAN-25	8.1	5.9	31.4
PCE	01/13/05	TSF-05A	5.0	5.0	NA
PCE	01/17/05	TAN-37B	5.0	5.0	NA
PCE	01/18/05	TAN-25	5.0	5.0	NA
PCE	01/24/05	TSF-05B	ND	ND	NA
PCE	01/31/05	TSF-05B	ND	ND	NA
PCE	02/14/05	TAN-29	19.5	20.5	5.0

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
PCE	02/15/05	TAN-25	ND	ND	NA
PCE	02/28/05	TSF-05B	ND	ND	NA
PCE	03/14/05	TAN-10A	ND	ND	NA
PCE	03/15/05	TAN-25	ND	ND	NA
PCE	03/29/05	TSF-05A	5.0	5.0	NA
PCE	04/11/05	TAN-10A	3.6	3.8	5.4
PCE	04/12/05	TAN-29	14.6	12.3	17.1
PCE	04/25/05	TSF-05B	ND	ND	NA
PCE	05/09/05	TSF-05B	5.0	5.0	NA
PCE	05/10/05	TSF-05A	5.0	5.0	NA
PCE	05/24/05	TAN-31	ND	ND	NA
PCE	06/14/05	TAN-27	5.0	5.0	NA
PCE	06/15/05	TAN-1861	5.0	5.0	NA
TCE	03/16/04	TAN-25	ND	ND	NA
TCE	03/18/04	TSF-05A	ND	ND	NA
TCE	03/22/04	TAN-31	5.0	5.0	NA
TCE	03/23/04	TAN-37A	5.0	5.0	NA
TCE	03/24/04	TAN-27	5.0	5.0	NA
TCE	04/05/04	TAN-31	ND	ND	NA
TCE	04/19/04	TAN-37B	5.0	5.0	NA
TCE	04/20/04	TAN-25	ND	ND	NA
TCE	05/11/04	TAN-25	ND	ND	NA
TCE	05/13/04	TSF-05A	5.0	5.0	NA
TCE	05/17/04	TAN-37C	ND	ND	NA
TCE	05/18/04	TAN-31	5.0	5.0	NA
TCE	05/19/04	TAN-10A	5.0	5.0	NA
TCE	06/01/04	TSF-05B	ND	ND	NA
TCE	06/14/04	TAN-37C	ND	ND	NA
TCE	06/15/04	TSF-05B	ND	ND	NA
TCE	06/16/04	TAN-27	5.0	5.0	NA
TCE	07/19/04	TAN-37B	trace	trace	NA
TCE	07/20/04	TAN-31	ND	ND	NA

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
TCE	07/21/04	TAN-10A	1.9	trace	NA
TCE	08/17/04	TSF-05B	5.0	5.0	NA
TCE	08/19/04	TSF-05A	ND	ND	NA
TCE	08/23/04	TAN-31	5.0	5.0	NA
TCE	08/24/04	TAN-28	5.4	5.7	5.4
TCE	08/25/04	TAN-10A	5.0	5.0	NA
TCE	09/07/04	TAN-25	ND	ND	NA
TCE	09/20/04	TAN-28	7.7	7.6	1.3
TCE	09/21/04	TAN-31	ND	ND	NA
TCE	10/12/04	TAN-25	94.5	93.3	1.3
TCE	10/14/04	TSF-05A	135.5	141.3	4.2
TCE	10/18/04	TAN-28	827.6	909.9	9.5
TCE	10/19/04	TAN-25	48.9	54.8	11.4
TCE	10/25/04	TAN-31	5.0	5.0	NA
TCE	11/01/04	TAN-31	5.0	5.0	NA
TCE	11/15/04	TAN-37C	5.3	5.7	7.3
TCE	11/16/04	TAN-25	5.0	5.0	NA
TCE	11/17/04	TAN-10A	5.6	6.1	8.6
TCE	12/13/04	TAN-37B	39.8	38.3	3.8
TCE	12/14/04	TAN-25	5.0	5.0	NA
TCE	01/11/05	TAN-25	73.5	70.8	3.7
TCE	01/13/05	TSF-05A	342.0	360.0	5.1
TCE	01/17/05	TAN-37B	45.9	47.0	2.4
TCE	01/18/05	TAN-25	117.8	108.0	8.7
TCE	01/24/05	TSF-05B	31.0	35.3	13.0
TCE	01/31/05	TSF-05B	5.0	5.0	NA
TCE	02/14/05	TAN-29	749.4	737.5	1.6
TCE	02/15/05	TAN-25	5.0	5.0	NA
TCE	02/28/05	TSF-05B	5.0	5.0	NA
TCE	03/14/05	TAN-10A	7.3	7.3	0.0
TCE	03/15/05	TAN-25	5.0	5.0	NA
TCE	03/29/05	TSF-05A	5.0	5.0	NA

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
TCE	04/11/05	TAN-10A	7.8	7.7	1.3
TCE	04/12/05	TAN-29	1,038.2	1,076.4	3.6
TCE	04/25/05	TSF-05B	5.0	5.0	NA
TCE	05/09/05	TSF-05B	5.0	5.0	NA
TCE	05/10/05	TSF-05A	5.0	5.0	NA
TCE	05/24/05	TAN-31	5.0	5.0	NA
TCE	06/14/05	TAN-27	34.3	34.7	1.2
TCE	06/15/05	TAN-1861	25.8	23.4	9.8
cis-DCE	03/16/04	TAN-25	34.9	35.3	1.1
cis-DCE	03/18/04	TSF-05A	205.3	276.7	29.6
cis-DCE	03/22/04	TAN-31	5.0	5.0	NA
cis-DCE	03/23/04	TAN-37A	46.3	46.0	0.7
cis-DCE	03/24/04	TAN-27	5.0	5.0	NA
cis-DCE	04/05/04	TAN-31	5.0	5.0	NA
cis-DCE	04/19/04	TAN-37B	33.0	36.1	9.0
cis-DCE	04/20/04	TAN-25	5.0	5.0	NA
cis-DCE	05/11/04	TAN-25	43.5	45.2	3.8
cis-DCE	05/13/04	TSF-05A	283.4	286.3	1.0
cis-DCE	05/17/04	TAN-37C	5.0	5.0	NA
cis-DCE	05/18/04	TAN-31	15.6	14.6	6.6
cis-DCE	05/19/04	TAN-10A	ND	ND	NA
cis-DCE	06/01/04	TSF-05B	110.5	117.1	5.8
cis-DCE	06/14/04	TAN-37C	5.0	5.0	NA
cis-DCE	06/15/04	TSF-05B	34.6	44.7	25.5
cis-DCE	06/16/04	TAN-27	5.0	5.0	NA
cis-DCE	07/19/04	TAN-37B	22.6	22.8	0.9
cis-DCE	07/20/04	TAN-31	trace	trace	NA
cis-DCE	07/21/04	TAN-10A	ND	ND	NA
cis-DCE	08/17/04	TSF-05B	204.0	207.9	1.9
cis-DCE	08/19/04	TSF-05A	99.0	95.6	3.5
cis-DCE	08/23/04	TAN-31	11.6	5.1	77.8
cis-DCE	08/24/04	TAN-28	87.2	89.8	2.9

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
cis-DCE	08/25/04	TAN-10A	5.0	5.0	NA
cis-DCE	09/07/04	TAN-25	268.7	224.8	17.8
cis-DCE	09/20/04	TAN-28	138.4	131.1	5.4
cis-DCE	09/21/04	TAN-31	2.4	2.3	4.3
cis-DCE	10/12/04	TAN-25	45.6	45.5	0.7
cis-DCE	10/14/04	TSF-05A	188.5	192.7	2.2
cis-DCE	10/18/04	TAN-28	123.6	133.9	8.0
cis-DCE	10/19/04	TAN-25	265.7	306.1	14.1
cis-DCE	10/25/04	TAN-31	126.7	102.9	20.7
cis-DCE	11/01/04	TAN-31	47.3	50.0	5.6
cis-DCE	11/15/04	TAN-37C	5.0	5.0	NA
cis-DCE	11/16/04	TAN-25	5.0	5.0	NA
cis-DCE	11/17/04	TAN-10A	ND	ND	NA
cis-DCE	12/13/04	TAN-37B	14.0	14.5	3.5
cis-DCE	12/14/04	TAN-25	5.0	5.0	NA
cis-DCE	01/11/05	TAN-25	48.8	46.6	4.6
cis-DCE	01/13/05	TSF-05A	311.2	315.8	1.5
cis-DCE	01/17/05	TAN-37B	19.1	19.2	0.5
cis-DCE	01/18/05	TAN-25	265.8	263.4	0.9
cis-DCE	01/24/05	TSF-05B	525.6	525.2	0.1
cis-DCE	01/31/05	TSF-05B	296.1	301.5	1.8
cis-DCE	02/14/05	TAN-29	87.2	87.4	0.2
cis-DCE	02/15/05	TAN-25	2.5	2.9	14.8
cis-DCE	02/28/05	TSF-05B	58.0	58.0	0.0
cis-DCE	03/14/05	TAN-10A	ND	ND	NA
cis-DCE	03/15/05	TAN-25	5.0	5.0	NA
cis-DCE	03/29/05	TSF-05A	5.0	5.0	NA
cis-DCE	04/11/05	TAN-10A	5.0	5.0	NA
cis-DCE	04/12/05	TAN-29	140.2	140.8	0.4
cis-DCE	04/25/05	TSF-05B	8.6	7.9	8.5
cis-DCE	05/09/05	TSF-05B	5.0	5.0	NA
cis-DCE	05/10/05	TSF-05A	5.0	5.0	NA

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
cis-DCE	05/24/05	TAN-31	5.0	5.0	NA
cis-DCE	06/14/05	TAN-27	5.0	5.0	NA
cis-DCE	06/15/05	TAN-1861	5.0	5.0	NA
trans-DCE	03/16/04	TAN-25	204.8	209.7	2.4
trans-DCE	03/18/04	TSF-05A	418.5	461.6	9.8
trans-DCE	03/22/04	TAN-31	278.9	251.0	10.5
trans-DCE	03/23/04	TAN-37A	202.6	190.9	5.9
trans-DCE	03/24/04	TAN-27	5.0	5.0	NA
trans-DCE	04/05/04	TAN-31	183.6	198.5	7.8
trans-DCE	04/19/04	TAN-37B	154.1	152.9	0.8
trans-DCE	04/20/04	TAN-25	167.0	169.3	1.4
trans-DCE	05/11/04	TAN-25	119.0	122.7	3.1
trans-DCE	05/13/04	TSF-05A	264.0	268.1	1.5
trans-DCE	05/17/04	TAN-37C	58.3	62.5	7.0
trans-DCE	05/18/04	TAN-31	177.0	169.0	4.6
trans-DCE	05/19/04	TAN-10A	5.0	5.0	NA
trans-DCE	06/01/04	TSF-05B	194.4	189.7	2.4
trans-DCE	06/14/04	TAN-37C	119.9	124.8	4.0
trans-DCE	06/15/04	TSF-05B	194.3	191.3	1.6
trans-DCE	06/16/04	TAN-27	5.0	5.0	NA
trans-DCE	07/19/04	TAN-37B	206.4	235.6	13.2
trans-DCE	07/20/04	TAN-31	229.1	202.4	12.4
trans-DCE	07/21/04	TAN-10A	trace	trace	NA
trans-DCE	08/17/04	TSF-05B	181.2	177.3	2.2
trans-DCE	08/19/04	TSF-05A	247.3	247.5	0.1
trans-DCE	08/23/04	TAN-31	128.0	122.7	4.2
trans-DCE	08/24/04	TAN-28	30.8	24.2	24.0
trans-DCE	08/25/04	TAN-10A	5.0	5.0	NA
trans-DCE	09/07/04	TAN-25	143.4	135.1	6.0
trans-DCE	09/20/04	TAN-28	103.7	96.3	7.4
trans-DCE	09/21/04	TAN-31	141.8	163.2	14.0
trans-DCE	10/12/04	TAN-25	123.2	123.5	0.2

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
trans-DCE	10/14/04	TSF-05A	266.2	272.2	2.2
trans-DCE	10/18/04	TAN-28	93.6	98.4	5.0
trans-DCE	10/19/04	TAN-25	132.0	143.8	8.6
trans-DCE	10/25/04	TAN-31	139.9	136.3	2.6
trans-DCE	11/01/04	TAN-31	128.7	135.6	5.2
trans-DCE	11/15/04	TAN-37C	162.0	154.1	5.0
trans-DCE	11/16/04	TAN-25	137.2	136.7	0.4
trans-DCE	11/17/04	TAN-10A	5.0	5.0	NA
trans-DCE	12/13/04	TAN-37B	268.6	254.7	5.3
trans-DCE	12/14/04	TAN-25	143.5	151.6	5.5
trans-DCE	01/11/05	TAN-25	120.8	117.6	2.7
trans-DCE	01/13/05	TSF-05A	220.2	221.8	0.7
trans-DCE	01/17/05	TAN-37B	273.3	272.7	0.2
trans-DCE	01/18/05	TAN-25	124.5	123.1	1.1
trans-DCE	01/24/05	TSF-05B	304.4	308.2	1.2
trans-DCE	01/31/05	TSF-05B	223.2	216.4	3.1
trans-DCE	02/14/05	TAN-29	49.9	54.4	8.6
trans-DCE	02/15/05	TAN-25	139.5	139.8	0.2
trans-DCE	02/28/05	TSF-05B	225.6	221.9	1.7
trans-DCE	03/14/05	TAN-10A	5.0	5.0	NA
trans-DCE	03/15/05	TAN-25	149.6	146.3	2.2
trans-DCE	03/29/05	TSF-05A	156.6	173.5	10.2
trans-DCE	04/11/05	TAN-10A	5.0	5.0	NA
trans-DCE	04/12/05	TAN-29	114.2	112.6	1.4
trans-DCE	04/25/05	TSF-05B	171.8	170.7	0.6
trans-DCE	05/09/05	TSF-05B	162.7	161.4	0.8
trans-DCE	05/10/05	TSF-05A	118.8	119.1	0.3
trans-DCE	05/24/05	TAN-31	101.2	104.3	3.0
trans-DCE	06/14/05	TAN-27	5.0	5.0	NA
trans-DCE	06/15/05	TAN-1861	22.6	21.5	4.99
VC	03/16/04	TAN-25	16.4	16.8	2.4
VC	03/18/04	TSF-05A	117.6	141.8	18.7

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
VC	03/22/04	TAN-31	5.0	5.0	NA
VC	03/23/04	TAN-37A	14.3	12.9	10.3
VC	03/24/04	TAN-27	ND	ND	NA
VC	04/05/04	TAN-31	5.0	5.0	NA
VC	04/19/04	TAN-37B	11.6	17.0	37.8
VC	04/20/04	TAN-25	5.0	5.0	NA
VC	05/11/04	TAN-25	12.0	14.5	18.9
VC	05/13/04	TSF-05A	91.9	92.7	0.9
VC	05/17/04	TAN-37C	5.0	5.0	NA
VC	05/18/04	TAN-31	5.0	5.0	NA
VC	05/19/04	TAN-10A	ND	ND	NA
VC	06/01/04	TSF-05B	5.0	5.0	NA
VC	06/14/04	TAN-37C	5.0	5.0	NA
VC	06/15/04	TSF-05B	12.9	17.4	29.7
VC	06/16/04	TAN-27	ND	ND	NA
VC	07/19/04	TAN-37B	9.2	5.3	53.8
VC	07/20/04	TAN-31	1.7	3.6	71.7
VC	07/21/04	TAN-10A	ND	ND	NA
VC	08/17/04	TSF-05B	98.6	89.5	9.7
VC	08/19/04	TSF-05A	58.8	54.0	8.5
VC	08/23/04	TAN-31	2.2	4.3	64.6
VC	08/24/04	TAN-28	7.0	2.5	94.7
VC	08/25/04	TAN-10A	2.2	4.7	72.5
VC	09/07/04	TAN-25	9.4	8.0	16.1
VC	09/20/04	TAN-28	9.6	7.6	23.3
VC	09/21/04	TAN-31	2.2	4.2	62.5
VC	10/12/04	TAN-25	21.3	21.5	0.9
VC	10/14/04	TSF-05A	115.7	113.8	1.7
VC	10/18/04	TAN-28	7.7	9.2	17.8
VC	10/19/04	TAN-25	29.1	27.9	4.2
VC	10/25/04	TAN-31	ND	ND	NA
VC	11/01/04	TAN-31	2.2	2.3	4.4

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
VC	11/15/04	TAN-37C	4.4	7.2	48.3
VC	11/16/04	TAN-25	3.6	3.9	8.0
VC	11/17/04	TAN-10A	7.5	2.8	91.3
VC	12/13/04	TAN-37B	8.0	8.5	6.1
VC	12/14/04	TAN-25	5.0	5.0	NA
VC	01/11/05	TAN-25	17.1	15.9	7.3
VC	01/13/05	TSF-05A	110.0	106.4	3.3
VC	01/17/05	TAN-37B	8.1	8.1	0.0
VC	01/18/05	TAN-25	44.4	41.7	6.3
VC	01/24/05	TSF-05B	102.9	103.9	1.0
VC	01/31/05	TSF-05B	78.3	78.3	0.0
VC	02/14/05	TAN-29	3.8	4.0	5.1
VC	02/15/05	TAN-25	4.1	4.2	2.4
VC	02/28/05	TSF-05B	23.8	23.5	1.3
VC	03/14/05	TAN-10A	ND	ND	NA
VC	03/15/05	TAN-25	4.0	3.9	2.5
VC	03/29/05	TSF-05A	21.6	21.9	1.4
VC	04/11/05	TAN-10A	ND	ND	NA
VC	04/12/05	TAN-29	3.8	3.7	2.7
VC	04/25/05	TSF-05B	8.1	7.7	5.1
VC	05/09/05	TSF-05B	13.1	12.4	5.5
VC	05/10/05	TSF-05A	12.2	12.0	1.7
VC	05/24/05	TAN-31	3.7	3.8	2.7
VC	06/14/05	TAN-27	ND	ND	NA
VC	06/15/05	TAN-1861	ND	ND	NA
Ethene	03/16/04	TAN-25	32.5	34.7	6.5
Ethene	03/18/04	TSF-05A	301.8	384.5	24.1
Ethene	03/22/04	TAN-31	4.7	5.0	6.2
Ethene	03/23/04	TAN-37A	5.5	5.9	7.0
Ethene	03/24/04	TAN-27	ND	ND	NA
Ethene	04/05/04	TAN-31	4.2	4.8	13.3
Ethene	04/19/04	TAN-37B	ND	ND	NA

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
Ethene	04/20/04	TAN-25	18.3	12.5	37.7
Ethene	05/11/04	TAN-25	33.2	27.2	19.9
Ethene	05/13/04	TSF-05A	417.3	376.7	10.2
Ethene	05/17/04	TAN-37C	4.6	3.1	39.0
Ethene	05/18/04	TAN-31	3.8	3.9	2.6
Ethene	05/19/04	TAN-10A	ND	ND	NA
Ethene	06/01/04	TSF-05B	54.2	73.4	30.1
Ethene	06/14/04	TAN-37C	4.7	6.7	35.1
Ethene	06/15/04	TSF-05B	102.2	110.5	7.8
Ethene	06/16/04	TAN-27	ND	ND	NA
Ethene	07/19/04	TAN-37B	8.9	7.4	18.4
Ethene	07/20/04	TAN-31	22.6	21.4	5.5
Ethene	07/21/04	TAN-10A	ND	ND	NA
Ethene	08/17/04	TSF-05B	417.9	487.7	15.4
Ethene	08/19/04	TSF-05A	190.2	215.4	12.4
Ethene	08/23/04	TAN-31	2.5	1.5	50.0
Ethene	08/24/04	TAN-28	ND	ND	NA
Ethene	08/25/04	TAN-10A	ND	ND	NA
Ethene	09/07/04	TAN-25	10.8	11.7	8.0
Ethene	09/20/04	TAN-28	ND	ND	NA
Ethene	09/21/04	TAN-31	ND	ND	NA
Ethene	10/12/04	TAN-25	23.0	30.3	27.4
Ethene	10/14/04	TSF-05A	158.8	178.8	11.8
Ethene	10/18/04	TAN-28	ND	ND	NA
Ethene	10/19/04	TAN-25	20.3	17.8	13.1
Ethene	10/25/04	TAN-31	ND	ND	NA
Ethene	11/01/04	TAN-31	ND	ND	NA
Ethene	11/15/04	TAN-37C	8.3	8.7	4.7
Ethene	11/16/04	TAN-25	19.8	22.4	12.3
Ethene	11/17/04	TAN-10A	ND	ND	NA
Ethene	12/13/04	TAN-37B	20.8	17.8	15.5
Ethene	12/14/04	TAN-25	70.5	74.1	5.0

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
Ethene	01/11/05	TAN-25	45.4	369.7	156.3
Ethene	01/13/05	TSF-05A	181.8	170.5	6.4
Ethene	01/17/05	TAN-37B	23.4	25.3	7.8
Ethene	01/18/05	TAN-25	18.5	20.2	8.8
Ethene	01/24/05	TSF-05B	176.5	167.1	5.5
Ethene	01/31/05	TSF-05B	152.1	122.6	21.5
Ethene	02/14/05	TAN-29	ND	ND	NA
Ethene	02/15/05	TAN-25	15.1	13.6	10.5
Ethene	02/28/05	TSF-05B	221.5	231.5	4.4
Ethene	03/14/05	TAN-10A	ND	ND	NA
Ethene	03/15/05	TAN-25	50.6	55.1	8.5
Ethene	03/29/05	TSF-05A	669.4	476.3	33.7
Ethene	04/11/05	TAN-10A	ND	ND	NA
Ethene	04/12/05	TAN-29	ND	ND	NA
Ethene	04/25/05	TSF-05B	369.9	368.5	0.4
Ethene	05/09/05	TSF-05B	358.9	356.3	0.7
Ethene	05/10/05	TSF-05A	329.9	337.1	2.2
Ethene	05/24/05	TAN-31	14.7	12.1	19.4
Ethene	06/14/05	TAN-27	ND	ND	NA
Ethene	06/15/05	TAN-1861	ND	ND	NA
Ethane	03/16/04	TAN-25	trace	trace	NA
Ethane	03/18/04	TSF-05A	trace	trace	NA
Ethane	03/22/04	TAN-31	trace	trace	NA
Ethane	03/23/04	TAN-37A	trace	trace	NA
Ethane	03/24/04	TAN-27	trace	trace	NA
Ethane	04/05/04	TAN-31	trace	trace	NA
Ethane	04/19/04	TAN-37B	trace	trace	NA
Ethane	04/20/04	TAN-25	trace	trace	NA
Ethane	05/11/04	TAN-25	trace	trace	NA
Ethane	05/13/04	TSF-05A	trace	trace	NA
Ethane	05/17/04	TAN-37C	trace	trace	NA
Ethane	05/18/04	TAN-31	trace	trace	NA

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
Ethane	05/19/04	TAN-10A	trace	trace	NA
Ethane	06/01/04	TSF-05B	trace	trace	NA
Ethane	06/14/04	TAN-37C	trace	trace	NA
Ethane	06/15/04	TSF-05B	trace	trace	NA
Ethane	06/16/04	TAN-27	ND	ND	NA
Ethane	07/19/04	TAN-37B	ND	ND	NA
Ethane	07/20/04	TAN-31	ND	ND	NA
Ethane	07/21/04	TAN-10A	ND	ND	NA
Ethane	08/17/04	TSF-05B	trace	trace	NA
Ethane	08/19/04	TSF-05A	trace	trace	NA
Ethane	08/23/04	TAN-31	ND	ND	NA
Ethane	08/24/04	TAN-28	ND	ND	NA
Ethane	08/25/04	TAN-10A	ND	ND	NA
Ethane	09/07/04	TAN-25	ND	ND	NA
Ethane	09/20/04	TAN-28	ND	ND	NA
Ethane	09/21/04	TAN-31	ND	ND	NA
Ethane	10/12/04	TAN-25	ND	ND	NA
Ethane	10/14/04	TSF-05A	ND	ND	NA
Ethane	10/18/04	TAN-28	ND	ND	NA
Ethane	10/19/04	TAN-25	ND	ND	NA
Ethane	10/25/04	TAN-31	ND	ND	NA
Ethane	11/01/04	TAN-31	ND	ND	NA
Ethane	11/15/04	TAN-37C	ND	ND	NA
Ethane	11/16/04	TAN-25	ND	ND	NA
Ethane	11/17/04	TAN-10A	ND	ND	NA
Ethane	12/13/04	TAN-37B	ND	ND	NA
Ethane	12/14/04	TAN-25	ND	ND	NA
Ethane	01/11/05	TAN-25	ND	ND	NA
Ethane	01/13/05	TSF-05A	ND	ND	NA
Ethane	01/17/05	TAN-37B	ND	ND	NA
Ethane	01/18/05	TAN-25	ND	ND	NA
Ethane	01/24/05	TSF-05B	ND	ND	NA

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
Ethane	01/31/05	TSF-05B	ND	ND	NA
Ethane	02/14/05	TAN-29	ND	ND	NA
Ethane	02/15/05	TAN-25	ND	ND	NA
Ethane	02/28/05	TSF-05B	ND	ND	NA
Ethane	03/14/05	TAN-10A	ND	ND	NA
Ethane	03/15/05	TAN-25	ND	ND	NA
Ethane	03/29/05	TSF-05A	ND	ND	NA
Ethane	04/11/05	TAN-10A	ND	ND	NA
Ethane	04/12/05	TAN-29	ND	ND	NA
Ethane	04/25/05	TSF-05B	ND	ND	NA
Ethane	05/09/05	TSF-05B	124.3	123.4	0.7
Ethane	05/10/05	TSF-05A	114.3	115.4	1.0
Ethane	05/24/05	TAN-31	ND	ND	NA
Ethane	06/14/05	TAN-27	ND	ND	NA
Ethane	06/15/04	TAN-1861	ND	ND	NA
Methane	03/16/04	TAN-25	6,296.7	7,062.2	11.5
Methane	03/18/04	TSF-05A	8,126.7	10,359.9	24.2
Methane	03/22/04	TAN-31	12,705.7	13,248.5	4.2
Methane	03/23/04	TAN-37A	16,405.5	14,477.9	12.5
Methane	03/24/04	TAN-27	4,172.4	3,056.0	30.9
Methane	04/05/04	TAN-31	15,706.6	16,482.7	4.8
Methane	04/19/04	TAN-37B	18,843.8	19,837.8	5.1
Methane	04/20/04	TAN-25	13,919.2	12,169.9	13.4
Methane	05/11/04	TAN-25	8,957.3	6,972.1	24.9
Methane	05/13/04	TSF-05A	16,001.1	13,528.2	16.7
Methane	05/17/04	TAN-37C	14,297.3	12,761.1	11.4
Methane	05/18/04	TAN-31	14,736.1	12,470.0	16.7
Methane	05/19/04	TAN-10A	4,974.4	3,505.0	34.7
Methane	06/01/04	TSF-05B	8,794.5	11,562.3	27.2
Methane	06/14/04	TAN-37C	21,201.0	26,705.4	23.0
Methane	06/15/04	TSF-05B	19,327.6	20,476.5	5.8
Methane	06/16/04	TAN-27	3,093.3	3,352.5	8.0

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
Methane	07/19/04	TAN-37B	16,266.6	15,852.1	2.6
Methane	07/20/04	TAN-31	18,291.0	17,297.2	5.6
Methane	07/21/04	TAN-10A	3,440.4	2,895.6	17.2
Methane	08/17/04	TSF-05B	16,974.5	20,263.0	17.7
Methane	08/19/04	TSF-05A	7,672.2	8,248.6	7.2
Methane	08/23/04	TAN-31	7,166.9	6,877.0	4.1
Methane	08/24/04	TAN-28	3,616.3	3,637.4	0.6
Methane	08/25/04	TAN-10A	4,097.8	4,432.5	7.8
Methane	09/07/04	TAN-25	8,835.1	9,478.0	7.0
Methane	09/20/04	TAN-28	3,256.3	3,661.9	11.7
Methane	09/21/04	TAN-31	15,955.8	20,405.8	24.5
Methane	10/12/04	TAN-25	10,895.4	12,907.1	16.9
Methane	10/14/04	TSF-05A	8,121.1	9,176.7	12.2
Methane	10/18/04	TAN-28	4,388.1	3,883.0	12.2
Methane	10/19/04	TAN-25	14,199.5	11,920.2	17.5
Methane	10/25/04	TAN-31	16,440.8	16,048.7	2.4
Methane	11/01/04	TAN-31	16,432.7	20,578.8	22.4
Methane	11/15/04	TAN-37C	33,903.4	34,165.7	0.8
Methane	11/16/04	TAN-25	13,506.6	15,045.6	10.8
Methane	11/17/04	TAN-10A	5,703.8	5,665.2	0.7
Methane	12/13/04	TAN-37B	19,587.8	16,544.2	16.9
Methane	12/14/04	TAN-25	19,654.3	19,836.0	0.9
Methane	01/11/05	TAN-25	10,996.3	10,151.5	8.0
Methane	01/13/05	TSF-05A	7,388.6	7,292.2	1.3
Methane	01/17/05	TAN-37B	18,967.4	19,938.8	5.2
Methane	01/18/05	TAN-25	12,699.0	13,416.9	5.5
Methane	01/24/05	TSF-05B	13,503.2	12,818.9	5.2
Methane	01/31/05	TSF-05B	13,628.6	10,310.1	27.7
Methane	02/14/05	TAN-29	2,826.8	3,055.1	7.8
Methane	02/15/05	TAN-25	10,929.2	12,140.0	10.5
Methane	02/28/05	TSF-05B	18,518.5	19,729.0	6.3
Methane	03/14/05	TAN-10A	5,745.1	5,793.9	0.9

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
Methane	03/15/05	TAN-25	14,586.3	16,139.7	10.1
Methane	03/29/05	TSF-05A	27,453.7	20,115.4	30.9
Methane	04/11/05	TAN-10A	5,684.4	5,424.3	4.7
Methane	04/12/05	TAN-29	4,435.3	4,685.4	5.5
Methane	04/25/05	TSF-05B	21,307.4	21,795.8	2.3
Methane	05/09/05	TSF-05B	20,429.9	20,470.9	0.2
Methane	05/10/05	TSF-05A	14,818.4	15,020.3	1.4
Methane	05/24/05	TAN-31	24,367.8	23,120.7	5.3
Methane	06/14/05	TAN-27	2,994.1	3,087.8	3.08
Methane	06/15/04	TAN-1861	8,645.9	8,891.7	2.80
Propionate	03/16/04	TAN-25	24.5	23.2	5.5
Propionate	03/18/04	TSF-05A	222.2	190.1	15.6
Propionate	03/22/04	TAN-31	282.2	270.3	4.3
Propionate	03/23/04	TAN-37A	2.5	2.5	NA
Propionate	03/24/04	TAN-27	2.5	2.5	NA
Propionate	04/05/04	TAN-31	13.3	19.4	37.3
Propionate	04/19/04	TAN-37B	2.5	2.5	NA
Propionate	04/20/04	TAN-25	2.5	2.5	NA
Propionate	05/11/04	TAN-25	33.4	34.3	2.7
Propionate	05/13/04	TSF-05A	1,081.8	1,194.6	9.9
Propionate	05/17/04	TAN-37C	2.5	2.5	NA
Propionate	05/18/04	TAN-31	515.4	439.2	16.0
Propionate	05/19/04	TAN-10A	2.5	2.5	NA
Propionate	06/01/04	TSF-05B	999.6	461.2	73.7
Propionate	06/14/04	TAN-37C	2.5	2.5	NA
Propionate	06/15/04	TSF-05B	74.3	81.1	8.8
Propionate	06/16/04	TAN-27	2.5	2.5	NA
Propionate	07/19/04	TAN-37B	2.5	2.5	NA
Propionate	07/20/04	TAN-31	2.5	2.5	NA
Propionate	07/21/04	TAN-10A	2.5	2.5	NA
Propionate	08/17/04	TSF-05B	60.1	98.9	48.8
Propionate	08/19/04	TSF-05A	256.6	405.8	45.0

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
Propionate	08/23/04	TAN-31	869.5	1,015.1	15.5
Propionate	08/24/04	TAN-28	2.5	2.5	NA
Propionate	08/25/04	TAN-10A	2.5	2.5	NA
Propionate	09/07/04	TAN-25	236.3	230.1	2.7
Propionate	09/20/04	TAN-28	2.5	2.5	NA
Propionate	09/21/04	TAN-31	6.0	9.7	47.1
Propionate	10/12/04	TAN-25	192.4	193.1	0.4
Propionate	10/14/04	TSF-05A	614.8	621.7	1.1
Propionate	10/18/04	TAN-28	ND	ND	NA
Propionate	10/19/04	TAN-25	1,854.4	1,853.9	0.03
Propionate	10/25/04	TAN-31	624.5	620.5	0.6
Propionate	11/01/04	TAN-31	52.6	53.3	1.3
Propionate	11/15/04	TAN-37C	ND	ND	NA
Propionate	11/16/04	TAN-25	ND	ND	NA
Propionate	11/17/04	TAN-10A	ND	ND	NA
Propionate	12/13/04	TAN-37B	ND	ND	NA
Propionate	12/14/04	TAN-25	ND	ND	NA
Propionate	01/11/05	TAN-25	154.8	157.3	1.6
Propionate	01/13/05	TSF-05A	586.5	526.9	10.7
Propionate	01/17/05	TAN-37B	ND	ND	NA
Propionate	01/18/05	TAN-25	1,121.1	886.7	23.4
Propionate	01/24/05	TSF-05B	528.6	523.0	1.1
Propionate	01/31/05	TSF-05B	113.4	141.7	22.2
Propionate	02/14/05	TAN-29	ND	ND	NA
Propionate	02/15/05	TAN-25	ND	ND	NA
Propionate	03/14/05	TAN-10A	ND	ND	NA
Propionate	03/15/05	TAN-25	ND	ND	NA
Propionate	04/11/05	TAN-10A	ND	ND	NA
Propionate	04/12/05	TAN-29	ND	ND	NA
Propionate	05/09/05	TSF-05B	ND	ND	NA
Propionate	05/10/05	TSF-05A	ND	ND	NA
Propionate	06/14/05	TAN-27	ND	ND	NA

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
Propionate	06/15/05	TAN-1861	ND	ND	NA
Butyrate	03/16/04	TAN-25	2.5	2.5	NA
Butyrate	03/18/04	TSF-05A	2.5	2.5	NA
Butyrate	03/22/04	TAN-31	2.5	2.5	NA
Butyrate	03/23/04	TAN-37A	2.5	2.5	NA
Butyrate	03/24/04	TAN-27	2.5	2.5	NA
Butyrate	04/05/04	TAN-31	2.5	2.5	NA
Butyrate	04/19/04	TAN-37B	2.5	2.5	NA
Butyrate	04/20/04	TAN-25	2.5	2.5	NA
Butyrate	05/11/04	TAN-25	2.5	2.5	NA
Butyrate	05/13/04	TSF-05A	2.5	2.5	NA
Butyrate	05/17/04	TAN-37C	2.5	2.5	NA
Butyrate	05/18/04	TAN-31	2.5	2.5	NA
Butyrate	05/19/04	TAN-10A	2.5	2.5	NA
Butyrate	06/01/04	TSF-05B	62.5	28.4	75.0
Butyrate	06/14/04	TAN-37C	2.5	2.5	NA
Butyrate	06/15/04	TSF-05B	2.5	2.5	NA
Butyrate	06/16/04	TAN-27	2.5	2.5	NA
Butyrate	07/19/04	TAN-37B	2.5	2.5	NA
Butyrate	07/20/04	TAN-31	2.5	2.5	NA
Butyrate	07/21/04	TAN-10A	2.5	2.5	NA
Butyrate	08/17/04	TSF-05B	2.5	2.5	NA
Butyrate	08/19/04	TSF-05A	22.7	42.3	60.3
Butyrate	08/23/04	TAN-31	319.7	371.4	15.0
Butyrate	08/24/04	TAN-28	2.5	2.5	NA
Butyrate	08/25/04	TAN-10A	2.5	2.5	NA
Butyrate	09/07/04	TAN-25	351.2	360.5	2.6
Butyrate	09/20/04	TAN-28	2.5	2.5	NA
Butyrate	09/21/04	TAN-31	3.4	4.3	23.4
Butyrate	10/12/04	TAN-25	32.7	33.8	3.3
Butyrate	10/14/04	TSF-05A	243.0	246.1	1.3
Butyrate	10/18/04	TAN-28	ND	ND	NA

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
Butyrate	10/19/04	TAN-25	1,459.6	1,431.9	1.9
Butyrate	10/25/04	TAN-31	183.3	182.5	0.4
Butyrate	11/01/04	TAN-31	11.3	11.5	1.8
Butyrate	11/15/04	TAN-37C	ND	ND	NA
Butyrate	11/16/04	TAN-25	ND	ND	NA
Butyrate	11/17/04	TAN-10A	ND	ND	NA
Butyrate	12/13/04	TAN-37B	ND	ND	NA
Butyrate	12/14/04	TAN-25	ND	ND	NA
Butyrate	01/11/05	TAN-25	87.9	87.1	0.9
Butyrate	01/13/05	TSF-05A	731.0	636.5	13.8
Butyrate	01/17/05	TAN-37B	ND	ND	NA
Butyrate	01/18/05	TAN-25	1,615.6	1,282.8	23.0
Butyrate	01/24/05	TSF-05B	730.8	728.0	0.4
Butyrate	01/31/05	TSF-05B	81.6	105.6	25.6
Butyrate	02/14/05	TAN-29	ND	ND	NA
Butyrate	02/15/05	TAN-25	ND	ND	NA
Butyrate	03/14/05	TAN-10A	ND	ND	NA
Butyrate	03/15/05	TAN-25	ND	ND	NA
Butyrate	04/11/05	TAN-10A	ND	ND	NA
Butyrate	04/12/05	TAN-29	ND	ND	NA
Butyrate	05/09/05	TSF-05B	ND	ND	NA
Butyrate	05/10/05	TSF-05A	ND	ND	NA
Butyrate	06/14/05	TAN-27	ND	ND	NA
Butyrate	06/15/05	TAN-1861	ND	ND	NA
Acetate	03/16/04	TAN-25	85	79	7.3
Acetate	03/18/04	TSF-05A	547	481.7	12.7
Acetate	03/22/04	TAN-31	293.1	275.8	6.1
Acetate	03/23/04	TAN-37A	2.5	2.5	NA
Acetate	03/24/04	TAN-27	2.5	2.5	NA
Acetate	04/05/04	TAN-31	17.7	19.1	7.6
Acetate	04/19/04	TAN-37B	2.5	2.5	NA
Acetate	04/20/04	TAN-25	43.8	48.3	9.8

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
Acetate	05/11/04	TAN-25	134.1	140.5	4.7
Acetate	05/13/04	TSF-05A	2160.9	2408.7	10.8
Acetate	05/17/04	TAN-37C	2.5	2.5	NA
Acetate	05/18/04	TAN-31	480.5	440.9	8.6
Acetate	05/19/04	TAN-10A	2.5	2.5	NA
Acetate	06/01/04	TSF-05B	1,666.3	853.6	64.5
Acetate	06/14/04	TAN-37C	2.5	2.5	NA
Acetate	06/15/04	TSF-05B	280.1	294.2	4.9
Acetate	06/16/04	TAN-27	2.5	2.5	NA
Acetate	07/19/04	TAN-37B	2.5	2.5	NA
Acetate	07/20/04	TAN-31	2.5	2.5	NA
Acetate	07/21/04	TAN-10A	2.5	2.5	NA
Acetate	08/17/04	TSF-05B	962.3	604.9	45.6
Acetate	08/19/04	TSF-05A	832.2	1,211.4	37.1
Acetate	08/23/04	TAN-31	1,134.8	1,363.1	18.3
Acetate	08/24/04	TAN-28	2.5	2.5	NA
Acetate	08/25/04	TAN-10A	2.5	2.5	NA
Acetate	09/07/04	TAN-25	493.8	592.2	18.1
Acetate	09/20/04	TAN-28	3.7	3.1	17.6
Acetate	09/21/04	TAN-31	18.5	23.2	22.5
Acetate	10/12/04	TAN-25	1,070.7	1,149.0	7.1
Acetate	10/14/04	TSF-05A	1,395.4	1,396.4	0.07
Acetate	10/18/04	TAN-28	9.0	7.3	20.9
Acetate	10/19/04	TAN-25	3,608.8	3,647.7	1.1
Acetate	10/25/04	TAN-31	675.4	664.2	1.7
Acetate	11/01/04	TAN-31	31.0	31.9	2.9
Acetate	11/15/04	TAN-37C	ND	ND	NA
Acetate	11/16/04	TAN-25	ND	ND	NA
Acetate	11/17/04	TAN-10A	ND	ND	NA
Acetate	12/13/04	TAN-37B	2.5	2.5	NA
Acetate	12/14/04	TAN-25	2.5	2.5	NA
Acetate	01/11/05	TAN-25	830.6	824.7	0.7

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
Acetate	01/13/05	TSF-05A	1,391.8	1,259.7	10.0
Acetate	01/17/05	TAN-37B	ND	ND	NA
Acetate	01/18/05	TAN-25	2,146.8	1,718.0	22.2
Acetate	01/24/05	TSF-05B	866.6	858.9	0.9
Acetate	01/31/05	TSF-05B	189.6	230.0	19.3
Acetate	02/14/05	TAN-29	ND	ND	NA
Acetate	02/15/05	TAN-25	ND	ND	NA
Acetate	03/14/05	TAN-10A	ND	ND	NA
Acetate	03/15/05	TAN-25	ND	ND	NA
Acetate	04/11/05	TAN-10A	ND	ND	NA
Acetate	04/12/05	TAN-29	ND	ND	NA
Acetate	05/09/05	TSF-05B	ND	ND	NA
Acetate	05/10/05	TSF-05A	ND	ND	NA
Acetate	06/14/05	TAN-27	ND	ND	NA
Acetate	06/15/05	TAN-1861	ND	ND	NA
Lactate	03/16/04	TAN-25	14,624.1	14,939.7	2.1
Lactate	03/18/04	TSF-05A	9,301.4	9,466.3	1.8
Lactate	03/22/04	TAN-31	943.5	939.5	0.4
Lactate	03/23/04	TAN-37A	0.117	0.117	NA
Lactate	03/24/04	TAN-27	0.117	0.117	NA
Lactate	04/05/04	TAN-31	14.9	15.0	0.6
Lactate	04/19/04	TAN-37B	0.117	0.117	NA
Lactate	04/20/04	TAN-25	0.117	0.117	NA
Lactate	05/11/04	TAN-25	16,651.4	16,261.1	2.4
Lactate	05/13/04	TSF-05A	8,996.6	9,064.3	0.7
Lactate	05/17/04	TAN-37C	0.117	0.117	NA
Lactate	05/18/04	TAN-31	582.7	580.9	0.3
Lactate	05/19/04	TAN-10A	0.117	0.117	NA
Lactate	06/01/04	TSF-05B	0.117	0.117	NA
Lactate	06/14/04	TAN-37C	0.117	0.117	NA
Lactate	06/15/04	TSF-05B	0.117	0.117	NA
Lactate	06/16/04	TAN-27	0.117	0.117	NA

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
Lactate	07/19/04	TAN-37B	0.117	0.117	NA
Lactate	07/20/04	TAN-31	0.117	0.117	NA
Lactate	07/21/04	TAN-10A	0.117	0.117	NA
Isobutyrate	08/17/04	TSF-05B	2.5	2.5	NA
Isobutyrate	08/19/04	TSF-05A	2.5	2.5	NA
Isobutyrate	08/23/04	TAN-31	2.5	2.5	NA
Isobutyrate	08/24/04	TAN-28	ND	ND	NA
Isobutyrate	08/25/04	TAN-10A	ND	ND	NA
Isobutyrate	09/07/04	TAN-25	103.9	85.9	19.0
Isobutyrate	09/20/04	TAN-28	ND	ND	NA
Isobutyrate	09/21/04	TAN-31	2.2	2.5	12.8
Isobutyrate	10/12/04	TAN-25	13.6	13.7	0.7
Isobutyrate	10/14/04	TSF-05A	10.9	11.1	1.8
Isobutyrate	10/18/04	TAN-28	ND	ND	NA
Isobutyrate	10/19/04	TAN-25	76.1	75.2	1.2
Isobutyrate	10/25/04	TAN-31	34.8	35.0	0.6
Isobutyrate	11/01/04	TAN-31	5.7	5.7	0.0
Isobutyrate	11/15/04	TAN-37C	ND	ND	NA
Isobutyrate	11/16/04	TAN-25	ND	ND	NA
Isobutyrate	11/17/04	TAN-10A	ND	ND	NA
Isobutyrate	12/13/04	TAN-37B	ND	ND	NA
Isobutyrate	12/14/04	TAN-25	ND	ND	NA
Isobutyrate	01/11/05	TAN-25	14.5	14.4	0.7
Isobutyrate	01/13/05	TSF-05A	10.2	10.4	1.9
Isobutyrate	01/17/05	TAN-37B	ND	ND	NA
Isobutyrate	01/18/05	TAN-25	49.4	51.2	3.6
Isobutyrate	01/24/05	TSF-05B	33.2	32.3	2.7
Isobutyrate	01/31/05	TSF-05B	32.6	40.4	21.4
Isobutyrate	02/14/05	TAN-29	ND	ND	NA
Isobutyrate	02/15/05	TAN-25	ND	ND	NA
Isobutyrate	03/14/05	TAN-10A	ND	ND	NA
Isobutyrate	03/15/05	TAN-25	ND	ND	NA

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
Isobutyrate	04/11/05	TAN-10A	ND	ND	NA
Isobutyrate	04/12/05	TAN-29	ND	ND	NA
Isobutyrate	05/09/05	TSF-05B	ND	ND	NA
Isobutyrate	05/10/05	TSF-05A	ND	ND	NA
Isobutyrate	06/14/05	TAN-27	ND	ND	NA
Isobutyrate	06/15/05	TAN-1861	ND	ND	NA
Isovalerate	08/17/04	TSF-05B	2.5	2.5	NA
Isovalerate	08/19/04	TSF-05A	2.5	2.5	NA
Isovalerate	08/23/04	TAN-31	2.5	2.5	NA
Isovalerate	08/24/04	TAN-28	ND	ND	NA
Isovalerate	08/25/04	TAN-10A	ND	ND	NA
Isovalerate	09/07/04	TAN-25	93.5	78.0	18.1
Isovalerate	09/20/04	TAN-28	ND	ND	NA
Isovalerate	09/21/04	TAN-31	2.5	2.5	NA
Isovalerate	10/12/04	TAN-25	20.5	21.2	3.4
Isovalerate	10/14/04	TSF-05A	19.4	19.3	0.5
Isovalerate	10/18/04	TAN-28	ND	ND	NA
Isovalerate	10/19/04	TAN-25	106.0	101.6	4.2
Isovalerate	10/25/04	TAN-31	70.3	71.2	1.3
Isovalerate	11/01/04	TAN-31	22.3	22.7	1.8
Isovalerate	11/15/04	TAN-37C	ND	ND	NA
Isovalerate	11/16/04	TAN-25	ND	ND	NA
Isovalerate	11/17/04	TAN-10A	ND	ND	NA
Isovalerate	12/13/04	TAN-37B	ND	ND	NA
Isovalerate	12/14/04	TAN-25	ND	ND	NA
Isovalerate	01/11/05	TAN-25	25.7	25.4	1.2
Isovalerate	01/13/05	TSF-05A	16.9	17.1	1.2
Isovalerate	01/17/05	TAN-37B	ND	ND	NA
Isovalerate	01/18/05	TAN-25	66.9	69.9	4.4
Isovalerate	01/24/05	TSF-05B	50.4	50.3	0.2
Isovalerate	01/31/05	TSF-05B	40.7	50.3	21.1
Isovalerate	02/14/05	TAN-29	ND	ND	NA

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
Isovalerate	02/15/05	TAN-25	ND	ND	NA
Isovalerate	03/14/05	TAN-10A	ND	ND	NA
Isovalerate	03/15/05	TAN-25	ND	ND	NA
Isovalerate	04/11/05	TAN-10A	ND	ND	NA
Isovalerate	04/12/05	TAN-29	ND	ND	NA
Isovalerate	05/09/05	TSF-05B	ND	ND	NA
Isovalerate	05/10/05	TSF-05A	ND	ND	NA
Isovalerate	06/14/05	TAN-27	ND	ND	NA
Isovalerate	06/15/05	TAN-1861	ND	ND	NA
Valerate	08/17/04	TSF-05B	ND	ND	NA
Valerate	08/19/04	TSF-05A	ND	ND	NA
Valerate	08/23/04	TAN-31	ND	ND	NA
Valerate	08/24/04	TAN-28	ND	ND	NA
Valerate	08/25/04	TAN-10A	ND	ND	NA
Valerate	09/07/04	TAN-25	23.1	17.6	27.0
Valerate	09/20/04	TAN-28	ND	ND	NA
Valerate	09/21/04	TAN-31	2.5	2.5	NA
Valerate	10/12/04	TAN-25	ND	ND	NA
Valerate	10/14/04	TSF-05A	ND	ND	NA
Valerate	10/18/04	TAN-28	ND	ND	NA
Valerate	10/19/04	TAN-25	27.9	27.4	1.8
Valerate	10/25/04	TAN-31	28.4	28.5	0.4
Valerate	11/01/04	TAN-31	ND	ND	NA
Valerate	11/15/04	TAN-37C	ND	ND	NA
Valerate	11/16/04	TAN-25	ND	ND	NA
Valerate	11/17/04	TAN-10A	ND	ND	NA
Valerate	12/13/04	TAN-37B	ND	ND	NA
Valerate	12/14/04	TAN-25	ND	ND	NA
Valerate	01/11/05	TAN-25	ND	ND	NA
Valerate	01/13/05	TSF-05A	3.9	3.9	0.0
Valerate	01/17/05	TAN-37B	ND	ND	NA
Valerate	01/18/05	TAN-25	24.9	25.8	3.6

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
Valerate	01/24/05	TSF-05B	30.0	29.7	1.0
Valerate	01/31/05	TSF-05B	13.7	16.9	20.9
Valerate	02/14/05	TAN-29	ND	ND	NA
Valerate	02/15/05	TAN-25	ND	ND	NA
Valerate	03/14/05	TAN-10A	ND	ND	NA
Valerate	03/15/05	TAN-25	ND	ND	NA
Valerate	04/11/05	TAN-10A	ND	ND	NA
Valerate	04/12/05	TAN-29	ND	ND	NA
Valerate	05/09/05	TSF-05B	ND	ND	NA
Valerate	05/10/05	TSF-05A	ND	ND	NA
Valerate	06/14/05	TAN-27	ND	ND	NA
Valerate	06/15/05	TAN-1861	ND	ND	NA
Hexanoate	08/17/04	TSF-05B	ND	ND	NA
Hexanoate	08/19/04	TSF-05A	ND	ND	NA
Hexanoate	08/23/04	TAN-31	ND	ND	NA
Hexanoate	08/24/04	TAN-28	ND	ND	NA
Hexanoate	08/25/04	TAN-10A	ND	ND	NA
Hexanoate	09/07/04	TAN-25	9.5	9.2	3.2
Hexanoate	09/20/04	TAN-28	ND	ND	NA
Hexanoate	09/21/04	TAN-31	ND	ND	NA
Hexanoate	10/12/04	TAN-25	ND	ND	NA
Hexanoate	10/14/04	TSF-05A	ND	ND	NA
Hexanoate	10/18/04	TAN-28	ND	ND	NA
Hexanoate	10/19/04	TAN-25	16.7	16.0	4.3
Hexanoate	10/25/04	TAN-31	9.8	9.7	1.0
Hexanoate	11/01/04	TAN-31	ND	ND	NA
Hexanoate	11/15/04	TAN-37C	ND	ND	NA
Hexanoate	11/16/04	TAN-25	ND	ND	NA
Hexanoate	11/17/04	TAN-10A	ND	ND	NA
Hexanoate	12/13/04	TAN-37B	ND	ND	NA
Hexanoate	12/14/04	TAN-25	ND	ND	NA
Hexanoate	01/11/05	TAN-25	ND	ND	NA

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
Hexanoate	01/13/05	TSF-05A	ND	ND	NA
Hexanoate	01/17/05	TAN-37B	ND	ND	NA
Hexanoate	01/18/05	TAN-25	10.4	11.1	6.5
Hexanoate	01/24/05	TSF-05B	10.3	10.0	3.0
Hexanoate	01/31/05	TSF-05B	7.5	9.0	18.2
Hexanoate	02/14/05	TAN-29	ND	ND	NA
Hexanoate	02/15/05	TAN-25	ND	ND	NA
Hexanoate	03/14/05	TAN-10A	ND	ND	NA
Hexanoate	03/15/05	TAN-25	ND	ND	NA
Hexanoate	04/11/05	TAN-10A	ND	ND	NA
Hexanoate	04/12/05	TAN-29	ND	ND	NA
Hexanoate	05/09/05	TSF-05B	ND	ND	NA
Hexanoate	05/10/05	TSF-05A	ND	ND	NA
Hexanoate	06/14/05	TAN-27	ND	ND	NA
Hexanoate	06/15/05	TAN-1861	ND	ND	NA
Formate	08/17/04	TSF-05B	ND	ND	NA
Formate	08/19/04	TSF-05A	ND	ND	NA
Formate	08/23/04	TAN-31	ND	ND	NA
Formate	08/24/04	TAN-28	ND	ND	NA
Formate	08/25/04	TAN-10A	ND	ND	NA
Formate	09/07/04	TAN-25	ND	ND	NA
Formate	09/20/04	TAN-28	ND	ND	NA
Formate	09/21/04	TAN-31	ND	ND	NA
Formate	10/12/04	TAN-25	ND	ND	NA
Formate	10/14/04	TSF-05A	ND	ND	NA
Formate	10/18/04	TAN-28	ND	ND	NA
Formate	10/19/04	TAN-25	ND	ND	NA
Formate	10/25/04	TAN-31	ND	ND	NA
Formate	11/01/04	TAN-31	ND	ND	NA
Formate	11/15/04	TAN-37C	ND	ND	NA
Formate	11/16/04	TAN-25	ND	ND	NA
Formate	11/17/04	TAN-10A	ND	ND	NA

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
Formate	12/13/04	TAN-37B	ND	ND	NA
Formate	12/14/04	TAN-25	ND	ND	NA
Formate	01/11/05	TAN-25	ND	ND	NA
Formate	01/13/05	TSF-05A	ND	ND	NA
Formate	01/17/05	TAN-37B	ND	ND	NA
Formate	01/18/05	TAN-25	ND	ND	NA
Formate	01/24/05	TSF-05B	ND	ND	NA
Formate	01/31/05	TSF-05B	ND	ND	NA
Formate	02/14/05	TAN-29	ND	ND	NA
Formate	02/15/05	TAN-25	ND	ND	NA
Formate	03/14/05	TAN-10A	ND	ND	NA
Formate	03/15/05	TAN-25	ND	ND	NA
Formate	04/11/05	TAN-10A	ND	ND	NA
Formate	04/12/05	TAN-29	ND	ND	NA
Formate	05/09/05	TSF-05B	ND	ND	NA
Formate	05/10/05	TSF-05A	ND	ND	NA
Formate	06/14/05	TAN-27	ND	ND	NA
Formate	06/15/05	TAN-1861	ND	ND	NA
Lactose	08/17/04	TSF-05B	14,833.8	12,682.9	15.6
Lactose	08/19/04	TSF-05A	1,807.5	2,542.8	33.8
Lactose	08/23/04	TAN-31	ND	ND	NA
Lactose	08/24/04	TAN-28	ND	ND	NA
Lactose	08/25/04	TAN-10A	ND	ND	NA
Lactose	09/07/04	TAN-25	ND	ND	NA
Lactose	09/20/04	TAN-28	ND	ND	NA
Lactose	09/21/04	TAN-31	ND	ND	NA
Lactose	10/12/04	TAN-25	12,265.8	10,078.3	19.6
Lactose	10/14/04	TSF-05A	2,849.5	3,898.8	31.1
Lactose	10/18/04	TAN-28	ND	ND	NA
Lactose	10/19/04	TAN-25	84.2	NR	NA
Lactose	10/25/04	TAN-31	ND	ND	NA
Lactose	11/01/04	TAN-31	ND	ND	NA

Table C-15. (continued).

Analyte	Date	Well	Sample (ug/L)	Duplicate (ug/L)	RPD (%)
Lactose	11/15/04	TAN-37C	ND	ND	NA
Lactose	11/16/04	TAN-25	ND	ND	NA
Lactose	11/17/04	TAN-10A	ND	ND	NA
Lactose	12/13/04	TAN-37B	ND	ND	NA
Lactose	12/14/04	TAN-25	ND	ND	NA
Lactose	01/11/05	TAN-25	11,403.6	10,867.1	4.8
Lactose	01/13/05	TSF-05A	5,458.3	4,211.3	25.8
Lactose	01/17/05	TAN-37B	ND	ND	NA
Lactose	01/18/05	TAN-25	50	50	0.0
Lactose	01/24/05	TSF-05B	ND	ND	NA
Lactose	01/31/05	TSF-05B	ND	ND	NA
Lactose	02/14/05	TAN-29	ND	ND	NA
Lactose	02/15/05	TAN-25	ND	ND	NA
Lactose	03/14/05	TAN-10A	ND	ND	NA
Lactose	03/15/05	TAN-25	ND	ND	NA
Lactose	04/11/05	TAN-10A	ND	ND	NA
Lactose	04/12/05	TAN-29	ND	ND	NA
Lactose	05/09/05	TSF-05B	ND	ND	NA
Lactose	05/10/05	TSF-05A	ND	ND	NA
Lactose	06/14/05	TAN-27	ND	ND	NA
Lactose	06/15/05	TAN-1861	ND	ND	NA

Table C-16. Off-site VOC duplicates.

Analyte	Date	Well	Sample (µg/L)	Flag	Duplicate (µg/L)	Flag	RPD (%)
PCE	05/17/04	TAN-37C	5	U	5	U	NA
PCE	05/18/04	TAN-31	5	U	5	UJ	NA
PCE	05/19/04	TAN-10A	3	J	3	J	0.0
PCE	11/15/04	TAN-37C	5	U	5	U	NA
PCE	11/16/04	TAN-25	5	U	5	U	NA
PCE	11/17/04	TAN-10A	5	U	5	U	NA
PCE	06/14/05	TAN-27	6		6		0.00
PCE	06/15/05	TAN-1861	5	U	5	U	NA

Table C-16. (continued).

Analyte	Date	Well	Sample (µg/L)	Flag	Duplicate (µg/L)	Flag	RPD (%)
TCE	05/17/04	TAN-37C	7	J	4	J	54.5
TCE	05/18/04	TAN-31	2	J	2	J	0.0
TCE	05/19/04	TAN-10A	8	J	8		0.0
TCE	11/15/04	TAN-37C	7		6		15.4
TCE	11/16/04	TAN-25	1	J	2	J	66.7
TCE	11/17/04	TAN-10A	7		7		0.0
TCE	06/14/05	TAN-27	37		39		5.26
TCE	06/15/05	TAN-1861	29		29		0.0
cis-DCE	05/17/04	TAN-37C	3	J	1	J	100.0
cis-DCE	05/18/04	TAN-31	1	J	2	J	66.7
cis-DCE	05/19/04	TAN-10A	5	UJ	5	U	NA
cis-DCE	11/15/04	TAN-37C	4	J	5	J	22.2
cis-DCE	11/16/04	TAN-25	2	J	2	J	0.0
cis-DCE	11/17/04	TAN-10A	5	U	5	U	NA
cis-DCE	06/14/05	TAN-27	5	U	1	J	NA
cis-DCE	06/15/05	TAN-1861	4	J	4	J	0.0
trans-DCE	05/17/04	TAN-37C	67		65		3.0
trans-DCE	05/18/04	TAN-31	150		150	J	0.0
trans-DCE	05/19/04	TAN-10A	2	J	2	J	0.0
trans-DCE	11/15/04	TAN-37C	130		130		0.0
trans-DCE	11/16/04	TAN-25	110		130		16.7
trans-DCE	11/17/04	TAN-10A	2	J	3	J	40.0
trans-DCE	06/14/05	TAN-27	5	J	5		0
trans-DCE	06/15/05	TAN-1861	20		24		18.18
VC	05/17/04	TAN-37C	2	U	2	U	NA
VC	05/18/04	TAN-31	2	U	2	UJ	NA
VC	05/19/04	TAN-10A	2	UJ	2	U	NA
VC	11/15/04	TAN-37C	3		3		0.0
VC	11/16/04	TAN-25	2	J	2		0.0
VC	11/17/04	TAN-10A	10	U	10	U	NA
VC	06/14/05	TAN-27	10	U	10	U	NA
VC	06/15/05	TAN-1861	10	U	10	U	NA

Table C-17. Tritium and Sr-90 duplicates.

Analyte	Date	Well	Sample (pCi/L)	+/-	MDA	Duplicate (pCi/L)	+/-	MDA	RPD (%)
Tritium	03/22/04	TAN-31	1,640	132	276	1,480	129	281	10.3
Tritium	04/20/04	TAN-25	2,520	131	319	2,470	132	324	2.0
Tritium	05/18/04	TAN-31	1,460	130	359	1,420	128	353	2.8
Tritium	06/15/04	TSF-05B	2,200	124	311	2,390	127	313	8.3
Tritium	07/20/04	TAN-31	1,580	150	425	1,330	149	435	17.2
Tritium	08/23/04	TAN-31	1,930	131	339	1,840	121	309	4.8
Tritium	09/21/04	TAN-31	1,460	136	384	1,540	137	383	5.3
Tritium	10/18/04	TAN-28	4,560	160	327	4,550	159	327	0.2
Tritium	10/19/04	TAN-25	2,380	194	385	2,060	185	386	14.4
Tritium	11/15/04	TAN-37C	1,700	105	272	1,670	104	272	1.8
Tritium	11/16/04	TAN-25	2,710	116	267	2,890	171	305	6.4
Tritium	11/17/04	TAN-10A	262	103	324	413	111	332	44.7
Tritium	12/13/04	TAN-37B	1,980	165	368	1,640	153	357	18.8
Tritium	12/14/04	TAN-25	3,060	176	305	2,980	174	304	2.6
Tritium	01/17/05	TAN-37B	2,180	159	320	2,010	154	319	8.1
Tritium	01/18/05	TAN-25	2,870	165	281	2,990	168	283	4.1
Tritium	02/14/05	TAN-29	2,030	156	323	2,040	157	324	0.5
Tritium	02/15/05	TAN-25	3,150	182	321	3,000	179	323	4.9
Tritium	03/14/05	TAN-10A	-18.7	93.9	318	-34.2	95.1	323	58.6
Tritium	03/15/05	TAN-25	2,700	135	319	2,490	130	314	8.1
Tritium	04/11/05	TAN-10A	218	99.9	325	163	99.1	326	28.9
Tritium	04/12/05	TAN-29	2,740	139	326	2,830	139	323	3.2
Tritium	05/09/05	TSF-05B	1,510	152	351	1,700	157	351	11.8
Tritium	05/10/05	TSF-05A	1,030	136	347	1,080	139	351	4.7
Tritium	06/14/05	TAN-27	800	111	284	668	103	271	18.0
Tritium	06/15/05	TAN-1861	614	107	290	354	118	379	53.7
Sr-90	03/22/04	TAN-31	902	99.4	0.676	922	103	0.74	2.2
Sr-90	04/20/04	TAN-25	489	70.6	0.728	459	61.8	0.619	6.3
Sr-90	05/18/04	TAN-31	1,030	156	0.804	1,230	194	0.992	17.7
Sr-90	06/15/04	TSF-05B	991	138	0.544	1,040	146	0.51	4.8
Sr-90	07/20/04	TAN-31	565	76.5	0.375	582	82.9	0.459	3.0
Sr-90	08/23/04	TAN-31	918	120	0.463	989	138	0.589	7.4
Sr-90	09/21/04	TAN-31	849	121	0.501	864	124	0.531	1.8

Table C-17. (continued).

Analyte	Date	Well	Sample (pCi/L)	+/-	MDA	Duplicate (pCi/L)	+/-	MDA	RPD (%)
Sr-90	10/19/04	TAN-25	1,540	213	0.515	1,370	172	0.567	11.7
Sr-90	11/16/04	TAN-25	932	132	1.01	791	98.3	0.874	16.4
Sr-90	12/14/04	TAN-25	858	129	0.634	798	110	0.509	7.2
Sr-90	01/18/05	TAN-25	2,410	296	0.555	2,610	370	0.635	8.0
Sr-90	02/15/05	TAN-25	1,120	21.3	0.745	1,110	22	0.556	0.9
Sr-90	03/15/05	TAN-25	929	20.2	2.08	874	38.8	1.82	6.1
Sr-90	04/12/05	TAN-25	713	10.8	1.24	666	9.44	0.996	6.8
Sr-90	05/10/05	TAN-25	675	8.9	0.761	603	8.83	0.90	11.3
Sr-90	06/14/05	TAN-25	669	8.17	0.4	638	8.1	0.51	4.7

The RPD for COD was met for 33 of 39 duplicate samples. The RPD for iron was met for 54 of 59 duplicate samples. The RPD for sulfate was met for 28 of 32 duplicate samples. The RPD for alkalinity was met for all (38) duplicate samples. The RPD for ammonia was met for five of six duplicate samples. The RPD for phosphate was met for five of seven duplicate samples. Lactose duplicate samples for five of the eight sampling events were not analyzed.

Percentages of duplicate sample RPDs less than 25%, less than 50%, and greater than 50% are shown in Table C-18 for the IRC and Table C-19 for off-site laboratories. For the IRC results, the TAN-29 TCE sample from September 20, 2004, and the VOC and E/E/M samples from September 7, 2004, were analyzed outside of their holding times. RPDs were not calculated when results were reported as not detected or trace and are not included Table C-18, as was the case for all ethane and formate duplicates. RPDs were calculated using off-site laboratory results that had been flagged as an estimated or undetected value. The TCE target RPD of 14% was met for all IRC duplicate samples and met for three of five off-site duplicate samples.

Table C-18. Percentages of RPDs for IRC duplicate samples.

Analyte	Percentage of Samples with <25% RPD	Percentage of Samples with <50% RPD	Percentage of Samples with >50% RPD
PCE	100	100	0
TCE	100	100	0
cis-DCE	82	95	5
trans-DCE	97	97	3
VC	47	68	32
Ethene	77	100	0
Methane	82	100	0
Propionate	71	94	6
Butyrate	67	67	33
Acetate	84	95	5
Lactate	100	100	0

Table C-18. (continued).

Analyte	Percentage of Samples with <25% RPD	Percentage of Samples with <50% RPD	Percentage of Samples with >50% RPD
Isobutyrate	100	100	0
Isovalerate	100	100	0
Valerate	0	100	0
Hexanoate	100	100	0
Lactose	67	100	0

Table C-19. Percentages of RPDs for off-site laboratory duplicate samples.

Analyte	Percentage of Samples with <25% RPD	Percentage of Samples with <50% RPD	Percentage of Samples with >50% RPD
PCE	100	100	0
TCE	80	80	20
cis-DCE	40	40	60
trans-DCE	100	100	0
VC	100	100	0
Tritium	81	90	10
Sr-90	100	100	0

C-1.3 Completeness

Completeness is calculated by comparing the number of samples planned (as listed in the Sampling and Analysis Plan [SAP] table for each sampling event) to the number of samples actually collected, as shown in the following equation:

$$\%C = \frac{Sn}{St} x100\% \quad \text{(C-4)}$$

where:

%C = percent completeness

S_n = number of samples collected

S_t = number of samples planned in the SAP table.

Completeness results are presented in Table C-20. This table shows the number of samples planned, the number of samples collected, and percent completeness. The values in the table include samples planned to be collected according to the GWMP. It does not include non-routine samples (e.g., microbiological) or samples collected for QA (e.g., duplicates, PE, trip blanks, and field blanks). As is shown in Table C-20, a percent completeness of 98.9% was achieved for the reporting period. Details are provided in the comments column.

Table C-20. Sample completeness for the reporting period.

Date	Number of Samples Planned	Number of Samples Collected	Percent Completeness (%)	Comments
March 16, 2004	20	20	100	
March 18, 2004	20	20	100	
March 22–24, 2004	130	130	100	Radiological designation removed from well TAN-1861, so the planned gamma screen sample was not collected from this well. This was not counted against completeness.
April 5, 2004	20	20	100	
April 19-20, 2004	130	130	100	
May 11, 2004	20	20	100	
May 13, 2004	20	20	100	
May 17–19, 2004	130	130	100	
June 1, 2004	20	20	100	
June 14–16, 2004	130	130	100	
July 19–21, 2004	130	130	100	
August 17, 2004	20	20	100	
August 19, 2004	20	20	100	
August 23–25, 2004	130	130	100	
September 7, 2004	20	20	100	
September 20–21, 2004	130	130	100	
October 12, 2004	24	24	100	Added additional samples for E/E/M comparison.
October 14, 2004	24	24	100	
October 18–20, 2004	131	131	100	
October 25, 2004	24	24	100	
November 1, 2004	24	24	100	
November 15–17, 2004	131	131	100	
December 13–14, 2004	134	134	100	
January 11, 2005	30	30	100	
January 13, 2005	30	30	100	
January 17–18, 2005	134	134	100	
January 24, 2005	30	30	100	
January 31, 2005	30	30	100	

Table C-20. (continued).

Date	Number of Samples Planned	Number of Samples Collected	Percent Completeness (%)	Comments
February 14–15, 2005	134	134	100	Dissolved gas samples were left off the SAP table, but were collected.
February 28, 2005	20	20	100	
March 14–15, 2005	134	134	100	
March 28–29, 2005	20	20	100	
April 11–12, 2005	134	134	100	
April 25, 2005	20	20	100	
May 9–10, 2005	134	134	100	
May 24, 2005	20	12	60	Pump inoperable in TSF-05.
June 13–15, 2005	134	134	100	Collected as part of the monthly ISB RA GWM.
Total	**2587**	**2578**	**98.9**	

C-2. REFERENCES

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INEEL, 2003, *In Situ Bioremediation Remedial Action Groundwater Monitoring Plan for Test Area North, Operable Unit 1-07B*, INEEL/EXT-2002-00779, Revision 2, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho, December 2003.

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